CANADA
DEPARTMENT OF MINES
HON. LOUIS CODERRE, MINISTER; A. P. LOW, DEPUTY MINISTER

GEOLOGICAL SURVEY
R. W. BROCK, DIRECTOR.

MEMOIR No. 23

# Geology
OF THE
# Coast and Islands
BETWEEN THE
# Strait of Georgia and Queen Charlotte Sound, B.C.

BY
J. AUSTEN BANCROFT

OTTAWA
GOVERNMENT PRINTING BUREAU
1913

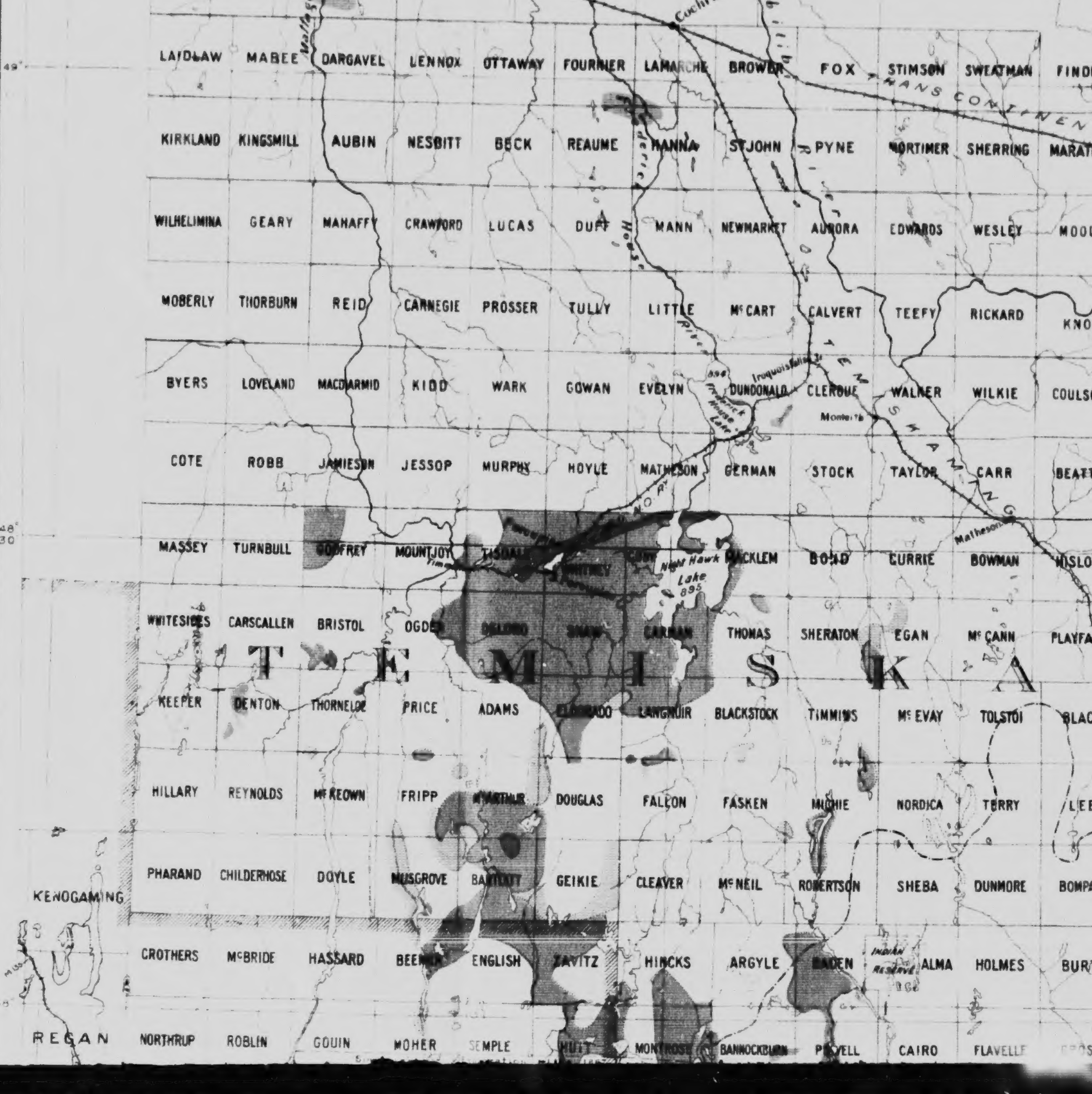
No. 1188

# SUDBURY—COBALT

## PROVINCE

*To accompany Part I, Vo*

Hon. W. H. Hearst, *Minister of Lands, Fores*



KENOGAMING

MAP

OF THE

...LT PORCUPINE REGION

...ICE OF ONTARIO.

..., Vol. 22, Report of Bureau of Mines, 1913.

...Forests and Mines.    Willet G. Miller, Provincial Geologist.

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Gibson, Deputy
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80°    79°

TABLE No 1

**Nickel Production, Sudbury Nickel Mines, 1889 to 1912**

| Calendar Year | Pounds of nickel in matte shipped. | Average price per lb. | Value | Calendar Year | Pounds of nickel in matte shipped. | Average price per lb. | Value |
|---|---|---|---|---|---|---|---|
| | | Cts. | $ | | | Cts. | $ |
| 1889 | *830,477 | 60 | 498,286 | 1901 | 9,189,047 | 50 | 4,594,523 |
| 1890 | 1,435,742 | 65 | 933,232 | 1902 | 10,693,410 | 47 | 5,025,903 |
| 1891 | 4,626,347 | 60 | 2,421,208 | 1903 | 12,505,510 | 40 | 5,002,204 |
| 1892 | 2,413,717 | 56 | 1,360,956 | 1904 | 10,547,883 | 40 | 4,219,153 |
| 1893 | 3,982,982 | 52 | 2,071,151 | 1905 | 18,876,315 | 40 | 7,550,526 |
| 1894 | 4,907,430 | 38½ | 1,870,958 | 1906 | 21,490,955 | 42 | 8,948,834 |
| 1895 | 3,888,525 | 35 | 1,360,984 | 1907 | 21,189,793 | 45 | 9,535,407 |
| 1896 | 3,397,113 | 35 | 1,188,990 | 1908 | 19,143,111 | 43 | 8,231,538 |
| 1897 | 3,997,647 | 35 | 1,399,176 | 1909 | 26,282,991 | 36 | 9,461,877 |
| 1898 | 5,517,690 | 33 | 1,820,838 | 1910 | 37,271,033 | 30 | 11,181,310 |
| 1899 | 5,744,000 | 36 | 2,067,840 | 1911 | 34,098,744 | 30 | 10,229,623 |
| 1900 | 7,080,227 | 47 | 3,327,707 | 1912 | 44,841,542 | 30 | 13,452,463 |

* Calculated from shipments made by rail.

TABLE No 2

***Copper Production in Ontario, 1886 to 1912.**

| Calendar Year | Lbs. | Value | Calendar Year | Lbs. | Value |
|---|---|---|---|---|---|
| | | $ | | | $ |
| 1886 | 165,000 | 18,150 | 1899 | 5,723,324 | 1,007,877 |
| 1887 | 322,524 | 38,284 | 1900 | 6,740,058 | 1,091,215 |
| 1888 | Nil | Nil | 1901 | 8,695,801 | 1,401,507 |
| 1889 | 1,466,752 | 201,678 | 1902 | 7,408,292 | 861,278 |
| 1890 | 1,306,965 | 206,233 | 1903 | 7,172,533 | 940,296 |
| 1891 | 4,127,097 | 581,234 | 1904 | 4,913,504 | 630,070 |
| 1892 | 2,203,795 | 254,538 | 1905 | 8,779,259 | 1,398,085 |
| 1893 | 3,641,504 | 291,461 | 1906 | 10,638,231 | 2,050,836 |
| 1894 | 5,207,679 | 497,854 | 1907 | 14,104,337 | 2,821,432 |
| 1895 | 4,576,337 | 492,114 | 1908 | 15,005,171 | 1,901,963 |
| 1896 | 3,167,256 | 344,508 | 1909 | 15,746,000 | 2,044,237 |
| 1897 | 5,500,652 | 621,023 | 1910 | 19,259,016 | 2,438,213 |
| 1898 | 8,375,223 | 1,007,530 | 1911 | 17,932,263 | 2,219,297 |
| | | | 1912 | 22,250,601 | 3,035,971 |

*Mainly from the nickel copper ores of the Sudbury area.

TABLE No 3

**Silver Production, Cobalt Mines, 1904 to 1912.**

| Year | Producing Mines | Shipments | | | Silver Contents | | | Av'ge Silver Contents per Ton. | | Value of Silver Shipments. | | | Total Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ore. | Concentrates | Bullion | Ore. | Concentrates | Bullion | Ore. | Concentrates | Ore. | Concentrates | Bullion | |
| | No. | Tons. | Tons. | oz. | oz. | oz. | oz. | oz. | oz. | $ | $ | $ | $ |
| 1904 | 4 | 158 | | | 206,875 | | | 1,309 | | 111,887 | | | 111,887 |
| 1905 | 16 | 2,144 | | | 2,451,196 | | | 1,143 | | 1,360,503 | | | 1,360,503 |
| 1906 | 17 | 5,335 | | | 5,401,766 | | | 1,013 | | 3,667,551 | | | 3,667,551 |
| 1907 | 28 | 14,788 | | | 10,023,311 | | | 677 | | 6,155,391 | | | 6,155,391 |
| 1908 | 30 | 24,487 | 1,117 | | 18,924,480 | 1,615,315 | | 770 | 1,444 | 8,468,243 | 665,085 | | 9,133,378 |
| 1909 | 31 | 27,729 | 2,048 | | 22,436,355 | 4,461,470 | | 809 | 1,174 | 10,809,673 | 1,651,704 | | 12,461,376 |
| 1910 | 41 | 27,437 | 6,845 | [illegible] | 22,881,714 | 7,084,814 | 960,043 | 801 | 1,030 | 11,180,439 | 3,590,028 | 527,460 | 15,478,047 |
| 1911 | 34 | 17,278 | 9,175 | 5,141,076 | 20,318,626 | 8,026,184 | 4,130,070 | 1,176 | 848 | 10,290,991 | 4,017,241 | 1,085,615 | 15,393,847 |
| 1912 | 32 | 10,719 | 11,214 | 5,089,127 | 14,195,804 | 9,768,226 | 5,085,107 | 807 | 871 | 8,766,871 | 5,556,919 | 3,085,144 | 17,408,934 |
| Ttl | ... | 130,075 | 31,319 | [illegible] | 116,837,087 | 30,775,116 | [illegible] | 898 | 944 | 60,451,848 | 15,481,047 | 5,208,220 | 81,731,115 |

TABLE No 4

**Gold Production, Porcupine Mines, 1911 and 1912.**

| Calendar Year | Quantity oz. | Value $ |
|---|---|---|
| 1911 | 644 | 12,910 |
| 1912 | 83,725 | 1,730,628 |

*Age relations of Rocks.*—It will be noted that there are extensive areas to be mapped before the sheet will be complete. Much work must also be accomplished before the age relationships of certain rocks will be definitely understood. For instance, it is uncertain whether or not the Sudbury series,consisting of quartzite, greywacke and slate, is of the same age as the Temiskaming series which is composed of similar sediments. Judging, however, from the facts that both series are much metamorphosed and have been tilted up into vertical attitudes by great masses of intrusive granites, it is possible that they are of the same age. The Sudbury series as mapped may also include sediments of the older Grenville series.

The Cobalt series, which is extensively developed at Cobalt, Gowganda, Temagami and other localities, consists of conglomerate, slate-like greywacke and quartzite. The rocks, mapped as "Animikie," in the Sudbury basin consist of conglomerate, tuff, slate and sandstone. These two series of sediments appear to have suffered about the same degree of metamorphism, and are probably of the same age. The Ramsay Lake conglomerate, exposed to the east of the town of Sudbury,may also be of the same age.

A word may be added in regard to the Grenville series. These sediments, which are exposed in immense volume 200 miles southeast of Sudbury beyond the confines of this map, are believed to be represented by what has formerly been known as the Keewatin "iron formation." The latter consists of banded ferruginous chert and jaspilyte, together with basal beds of schistose greywacke as may be seen near the railway station at Temagami. Small areas of crystalline limestone south of the Sudbury area and north of Rutherglen on the C. P. Ry., probably also should be classed with the Grenville series.

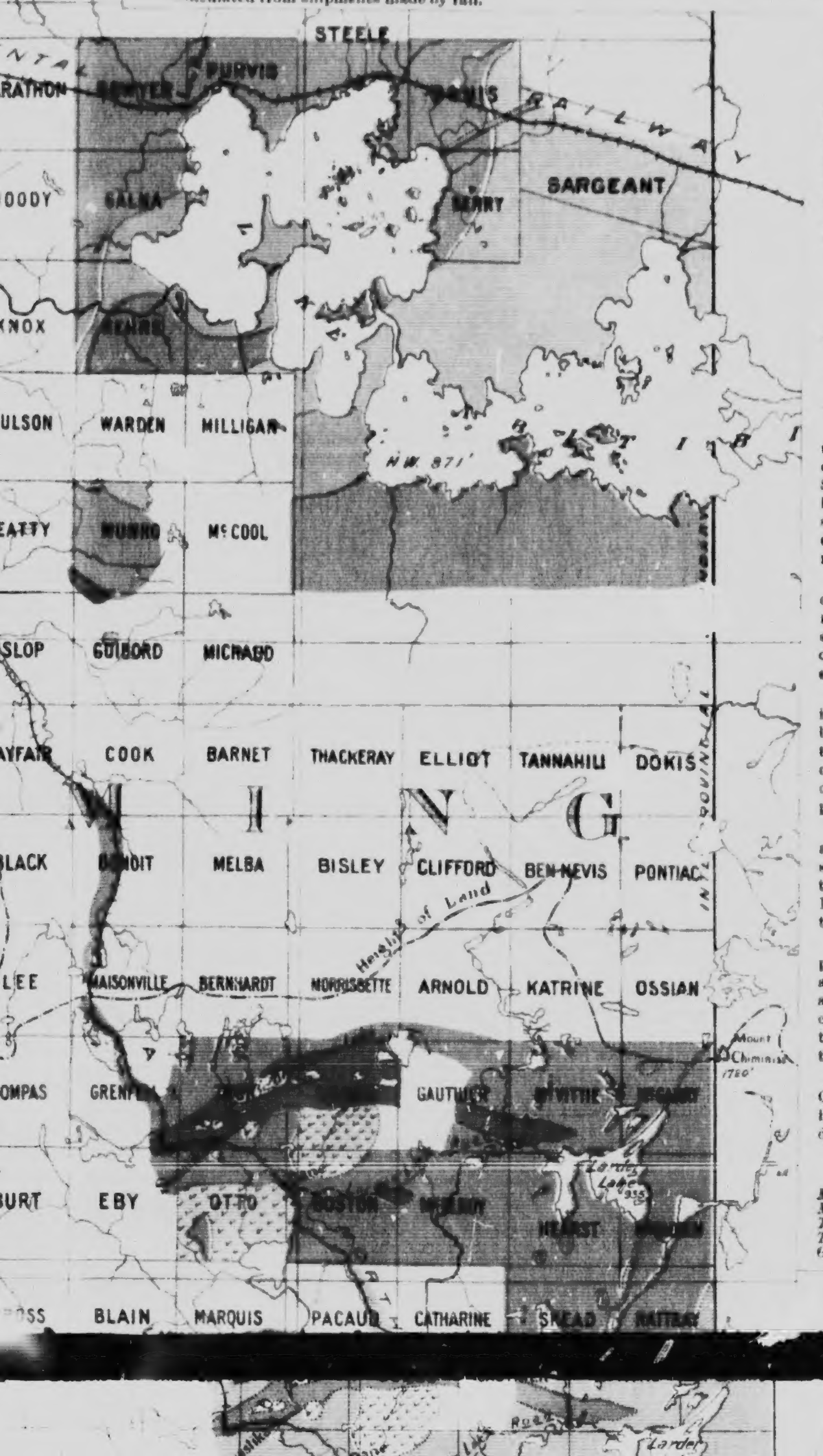
The age relations of the sediments on the north shore of lake Huron (the original Huronian area of Sir William Logan) to the Temiskaming, Sudbury and Cobalt series are not fully understood. Hence, on account of this incomplete knowledge, it has been considered prudent to use three legends, the first of which refers to the original Huronian area on the north shore of Lake Huron, the second to the Sudbury area, and the third to all the remaining parts shown on the map.

While the age relations of the sediments mentioned above are still uncertain, it seems probable that the identity in age of the Nipissing diabase, which is exposed in the Cobalt area, and the Nickel eruptive, which is exposed at Sudbury, is established. These intrusives intersect all of the pre-Cambrian sediments of the area, are very similar in chemical and lithological composition, and show similar magmatic differentiation. Both rocks occur in the form of sills, the Nipissing diabase having a thickness of 800 feet or more, and the Nickel eruptive according to A. P. Coleman, of a mile and a quarter.

*Ore Deposits.*—The ore deposits at Sudbury, Cobalt and Porcupine are classified as of pre-Cambrian age, and are believed to owe their origin to igneous intrusions. At Sudbury the intrusive rock is quartz norite (the Nickel eruptive), at Cobalt quartz-diabase (the Nipissing diabase), and at Porcupine granite.

SOURCES OF INFORMATION

*Maps of the Ontario Bureau of Mines,* Willet G. Miller, *Provincial Geologist.*
*Maps of the Canadian Geological Survey,* R. W. Brock, *Director.*
*T. and N. O. Ry. map showing geology between Porcupine and Gowganda, by* J. G. McMillan.
*Topography compiled under the direction of* W. R. Rogers, *Topographer, Bureau of Mines.*
*Geology compiled by* A. G. Burrows *and* Cyril W. Knight.

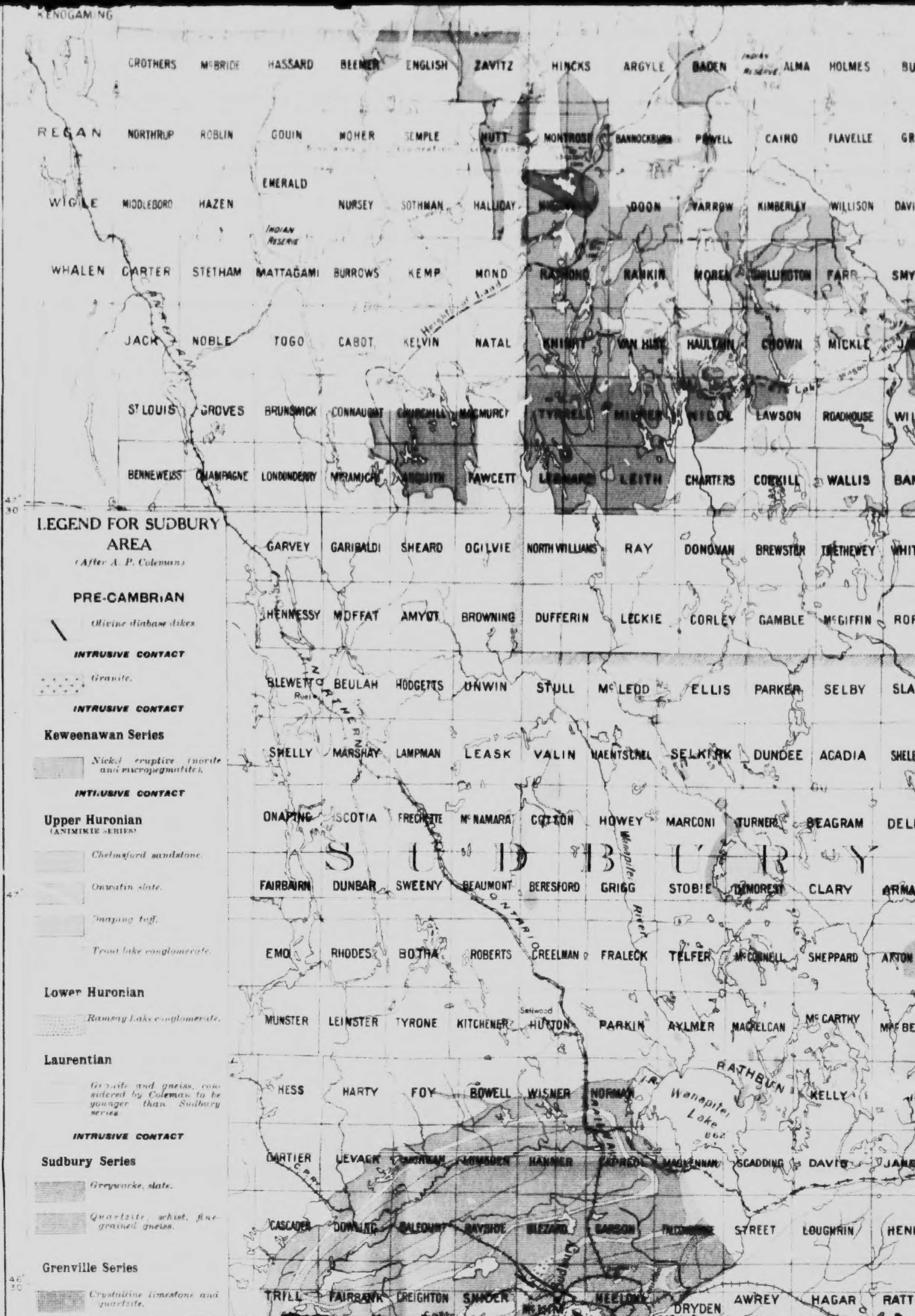


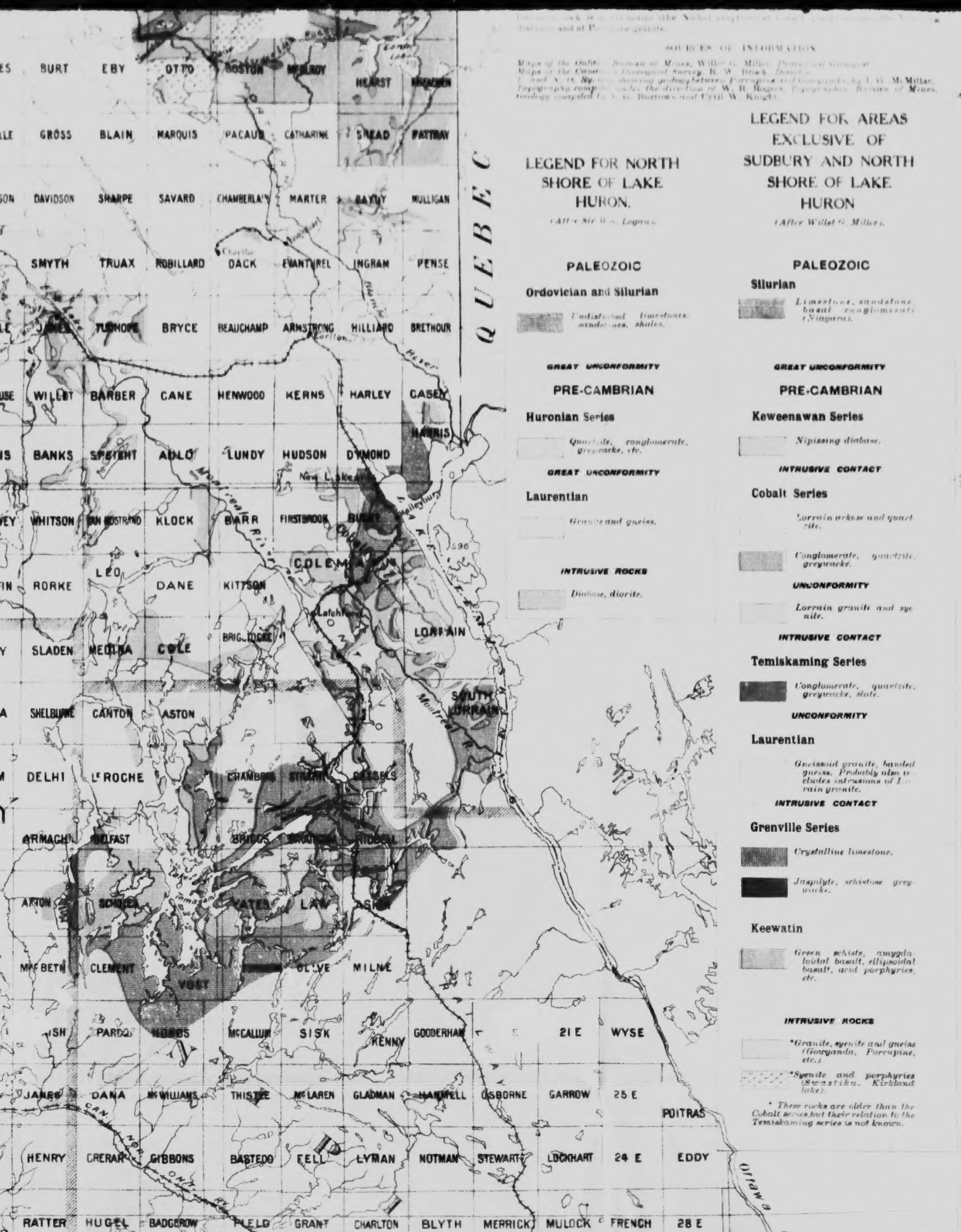

48°

LEGEND FOR AREAS
EXCLUSIVE OF

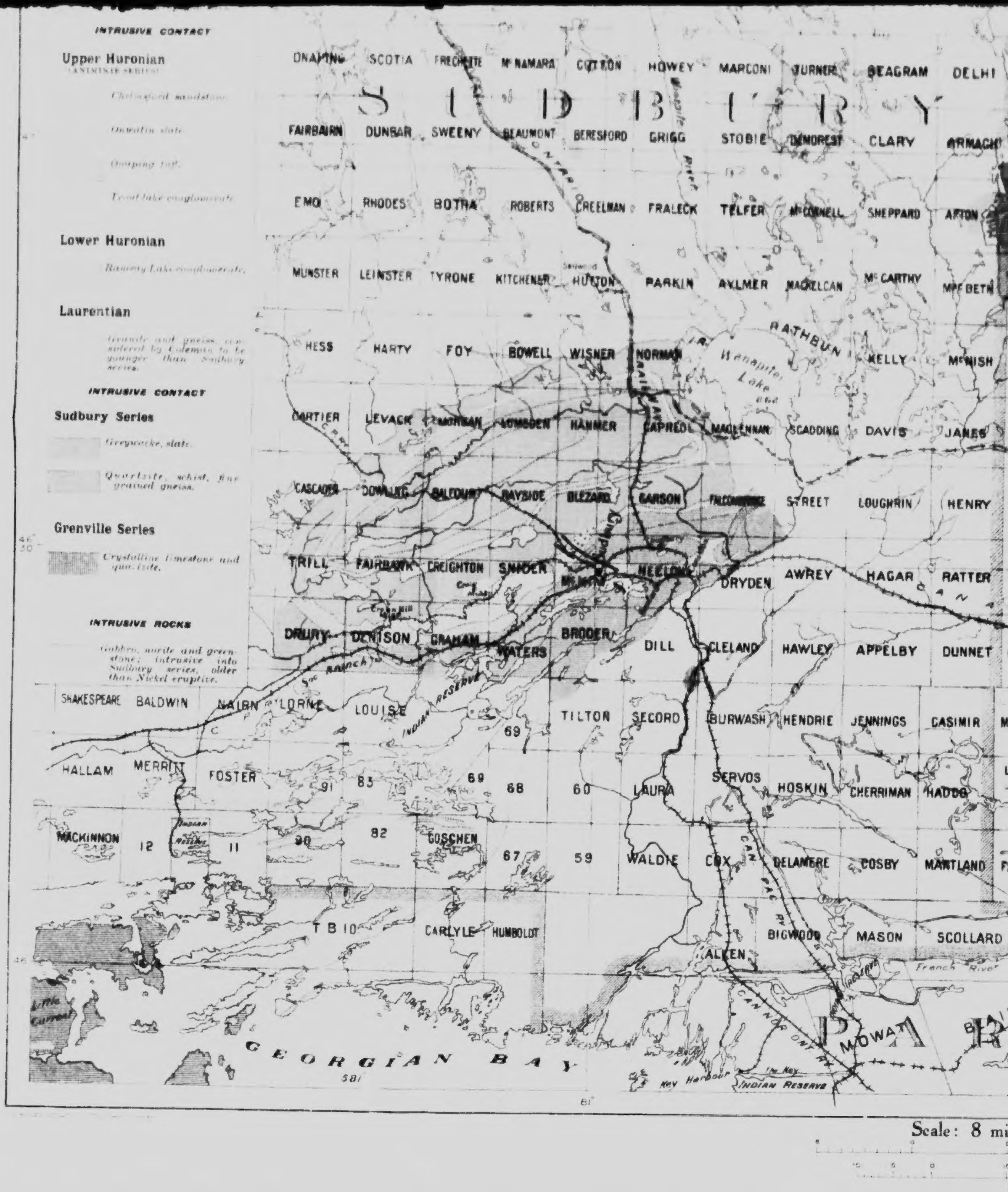
intrusive rock is quartz norite (the Nickel eruptive), at Cobalt quartz-diabase (the Nipissing diabase), and at Porcupine granite.

SOURCES OF INFORMATION


KENOGAMING
CROTHERS
McBRIDE
HASSARD
BEEMER
ENGLISH
ZAVITZ
HINCKS
ARGYLE
BADEN
Indian Reserve
ALMA
HOLMES
REGAN
NORTHRUP
ROBLIN
GOUIN
MOHER
SEMPLE
HUTT
MONTROSE
BANNOCKBURN
POWELL
CAIRO
FLAVELLE
EMERALD
WIGLE
MIDDLEBORO
HAZEN
NURSEY
SOTHMAN
HALLIDAY
DOON
YARROW
KIMBERLEY
WILLISON
Indian Reserve
WHALEN
CARTER
STETHAM
MATTAGAMI
BURROWS
KEMP
MOND
RAYMOND
RANKIN
MOREL
WELLINGTON
FARR
Height of Land
JACK
NOBLE
TOGO
CABOT
KELVIN
NATAL
KNIGHT
VAN HISE
HAULTAIN
CHOWN
MICKLE
ST LOUIS
GROVES
BRUNSWICK
CONNAUGHT
CHURCHILL
MACMURCHY
TYRRELL
MILNER
NICOL
LAWSON
ROADHOUSE
BENNEWEISS
CHAMPAGNE
LONDONDERRY
MIRAMICHI
ASQUITH
FAWCETT
LEONARD
LEITH
CHARTERS
CORKILL
WALLIS
47° 30
LEGEND FOR SUDBURY AREA
(After A. P. Coleman)
PRE-CAMBRIAN
Olivine diabase dikes
INTRUSIVE CONTACT
Granite.
INTRUSIVE CONTACT
Keweenawan Series
Nickel eruptive (norite and micropegmatite).
INTRUSIVE CONTACT
Upper Huronian
(ANIMIKIE SERIES)
Chelmsford sandstone.
Onwatin slate.
Onaping tuff.
Trout lake conglomerate.
Lower Huronian
Ramsay Lake conglomerate.
Laurentian
Granite and gneiss, considered by Coleman to be younger than Sudbury series
INTRUSIVE CONTACT
Sudbury Series
Greywacke, slate.
Quartzite, schist, fine-grained gneiss.
Grenville Series
Crystalline limestone and quartzite.
47°
46° 30
GARVEY
GARIBALDI
SHEARD
OGILVIE
NORTH WILLIAMS
RAY
DONOVAN
BREWSTER
TRETHEWEY
HENNESSY
MOFFAT
AMYOT
BROWNING
DUFFERIN
LECKIE
CORLEY
GAMBLE
McGIFFIN
BLEWETT
BEULAH
HODGETTS
UNWIN
STULL
McLEOD
ELLIS
PARKER
SELBY
SHELLY
MARSHAY
LAMPMAN
LEASK
VALIN
HAENTSCHEL
SELKIRK
DUNDEE
ACADIA
ONAPING
SCOTIA
FRECHETTE
McNAMARA
COTTON
HOWEY
MARCONI
TURNER
SEAGRAM
SUDBURY
FAIRBAIRN
DUNBAR
SWEENY
BEAUMONT
BERESFORD
GRIGG
STOBIE
DEMOREST
CLARY
Wanapitei River
EMO
RHODES
BOTHA
ROBERTS
CREELMAN
FRALECK
TELFER
McCONNELL
SHEPPARD
MUNSTER
LEINSTER
TYRONE
KITCHENER
HUTTON
PARKIN
AYLMER
MACKELCAN
McCARTHY
RATHBUN
HESS
HARTY
FOY
BOWELL
WISNER
NORMAN
Wanapitei Lake
862
KELLY
CARTIER
LEVACK
SCADDING
DAVIS
CASCADEN
STREET
LOUGHRIN
TRILL
FAIRBANK
CREIGHTON
SNIDER
DRYDEN
AWREY
HAGAR



SOURCES OF INFORMATION
LEGEND FOR NORTH SHORE OF LAKE HURON.
(After Sir W. Logan.)
PALEOZOIC
Ordovician and Silurian
Undisturbed limestones, sandstones, shales.
GREAT UNCONFORMITY
PRE-CAMBRIAN
Huronian Series
Quartzite, conglomerate, greywacke, etc.
GREAT UNCONFORMITY
Laurentian
Granite and gneiss.
INTRUSIVE ROCKS
Diabase, diorite.
LEGEND FOR AREAS EXCLUSIVE OF SUDBURY AND NORTH SHORE OF LAKE HURON
(After Willet G. Miller.)
PALEOZOIC
Silurian
Limestone, sandstone, basal conglomerate (Niagara).
GREAT UNCONFORMITY
PRE-CAMBRIAN
Keweenawan Series
Nipissing diabase.
INTRUSIVE CONTACT
Cobalt Series
Lorrain arkose and quartzite.
Conglomerate, quartzite, greywacke.
UNCONFORMITY
Lorrain granite and syenite.
INTRUSIVE CONTACT
Temiskaming Series
Conglomerate, quartzite, greywacke, slate.
UNCONFORMITY
Laurentian
Gneissoid granite, banded gneiss. Probably also includes intrusions of Lorrain granite.
INTRUSIVE CONTACT
Grenville Series
Crystalline limestone.
Jaspilyte, schistose greywacke.
Keewatin
Green schists, amygdaloidal basalt, ellipsoidal basalt, acid porphyries, etc.
INTRUSIVE ROCKS
*Granite, syenite and gneiss (Gowganda, Porcupine, etc.)
*Syenite and porphyries (Swastika, Kirkland lake).
* These rocks are older than the Cobalt series but their relation to the Temiskaming series is not known.
QUEBEC
BURT
EBY
OTTO
BOSTON
HEARST
GROSS
BLAIN
MARQUIS
PACAUD
CATHARINE
DAVIDSON
SHARPE
SAVARD
MARTER
MULLIGAN
SMYTH
TRUAX
ROBILLARD
DACK
EVANTUREL
INGRAM
PENSE
BRYCE
BEAUCHAMP
ARMSTRONG
HILLIARD
BRETHOUR
BARBER
CANE
HENWOOD
KERNS
HARLEY
CASEY
HARRIS
BANKS
LUNDY
HUDSON
DYMOND
New Liskeard
WHITSON
KLOCK
BARR
FIRSTBROOK
COLEMAN
LEO
RORKE
DANE
KITTSON
LORRAIN
SLADEN
COLE
SOUTH LORRAIN
SHELBURNE
CANTON
ASTON
DELHI
LE ROCHE
CHAMBERS
ARMAGH
BELFAST
BRIGGS
MILNE
CLEMENT
SISK
KENNY
GOODERHAM
21 E
WYSE
PARDO
HOBBS
McCALLUM
DANA
McWILLIAMS
THISTLE
McLAREN
GLADMAN
OSBORNE
GARROW
25 E
POITRAS
HENRY
CRERAR
GIBBONS
BASTEDO
FELL
LYMAN
NOTMAN
STEWART
LOCKHART
24 E
EDDY
Ottawa R.
RATTER
HUGEL
BADGEROW
GRANT
CHARLTON
BLYTH
MERRICK
MULOCK
FRENCH
28 E



INTRUSIVE CONTACT
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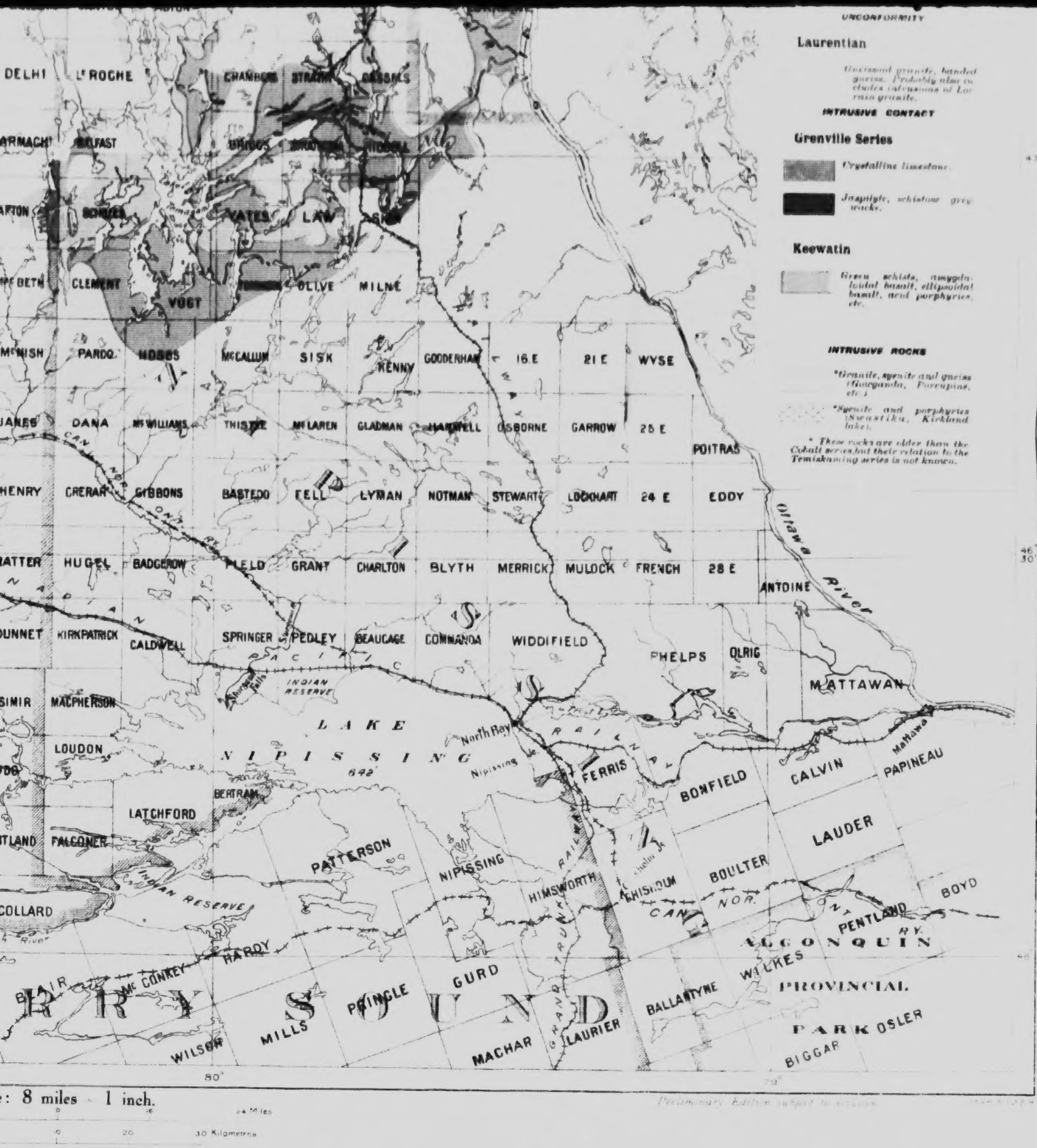
Quartzite, schist, fine grained gneiss.
Grenville Series
Crystalline limestone and quartzite.
INTRUSIVE ROCKS
Gabbro, norite and greenstone; intrusive into Sudbury series, older than Nickel eruptive.
SUDBURY
ONAPING
SCOTIA
FRECHETTE
McNAMARA
COTTON
HOWEY
MARCONI
TURNER
BEAGRAM
DELHI
FAIRBAIRN
DUNBAR
SWEENY
BEAUMONT
BERESFORD
GRIGG
STOBIE
DENOREST
CLARY
ARMAGH
EMO
RHODES
BOTHA
ROBERTS
CREELMAN
FRALECK
TELFER
McCONNELL
SHEPPARD
AFTON
MUNSTER
LEINSTER
TYRONE
KITCHENER
HUTTON
PARKIN
AYLMER
MACKELCAN
McCARTHY
McBETH
RATHBUN
Wanapitei Lake
HESS
HARTY
FOY
BOWELL
WISNER
NORMAN
KELLY
McNISH
CARTIER
LEVACK
MORGAN
LUMSDEN
HANMER
CAPREOL
MACLENNAN
SCADDING
DAVIS
JAMES
CASCADEN
DOWLING
BALFOUR
RAYSIDE
BLEZARD
GARSON
FALCONBRIDGE
STREET
LOUGHRIN
HENRY
TRILL
FAIRBANK
CREIGHTON
SNIDER
McKIM
NEELON
DRYDEN
AWREY
HAGAR
RATTER
DRURY
DENISON
GRAHAM
WATERS
BRODER
DILL
CLELAND
HAWLEY
APPELBY
DUNNET
SHAKESPEARE
BALDWIN
NAIRN
LORNE
LOUISE
INDIAN RESERVE
TILTON
SECORD
BURWASH
HENDRIE
JENNINGS
CASIMIR
HALLAM
MERRITT
FOSTER
91
83
69
68
60
LAURA
SERVOS
HOSKIN
CHERRIMAN
HADDO
MACKINNON
12
11
90
82
GOSCHEN
67
59
WALDIE
COX
DELAMERE
COSBY
MARTLAND
T B 10
CARLYLE
HUMBOLDT
BIGWOOD
MASON
SCOLLARD
ALLEN
French River
MOWAT
CAN PAC RY
CAN NOR ONT RY
GEORGIAN BAY
Key Harbour
INDIAN RESERVE
Little Current
Scale: 8 mi


UNCONFORMITY
Laurentian
Gneissoid granite, banded gneiss. Probably also includes intrusions of Lorrain granite.
INTRUSIVE CONTACT
Grenville Series
Crystalline limestone.
Jaspilyte, schistose greywacke.
Keewatin
Green schists, amygdaloidal basalt, ellipsoidal basalt, acid porphyries, etc.
INTRUSIVE ROCKS
*Granite, syenite and gneiss (Gowganda, Porcupine, etc.)
*Syenite and porphyries (Swastika, Kirkland lake).
* These rocks are older than the Cobalt series, but their relation to the Temiskaming series is not known.
DELHI
L'ROCHE
CHAMBERS
STRATHY
GIBBONS
BELFAST
BRIGGS
YATES
LAW
CLEMENT
VOGT
OLIVE
MILNE
PARDO
HOBBS
McCALLUM
SISK
KENNY
GOODERHAM
16 E
21 E
WYSE
DANA
McWILLIAMS
THISTLE
McLAREN
GLADMAN
OSBORNE
GARROW
25 E
POITRAS
HENRY
CRERAR
GIBBONS
BASTEDO
FELL
LYMAN
NOTMAN
STEWART
LOCKHART
24 E
EDDY
Ottawa River
HUGEL
BADGEROW
FIELD
GRANT
CHARLTON
BLYTH
MERRICK
MULOCK
FRENCH
28 E
ANTOINE
KIRKPATRICK
CALDWELL
SPRINGER
PEDLEY
BEAUCAGE
COMMANDA
WIDDIFIELD
PHELPS
OLRIG
MATTAWAN
CANADIAN PACIFIC
CAN. NOR. ONT. RY.
INDIAN RESERVE
MACPHERSON
LAKE NIPISSING
642
North Bay
Nipissing Jc.
FERRIS
BONFIELD
CALVIN
PAPINEAU
Mattawa
LOUDON
LATCHFORD
BERTRAM
FALCONER
PATTERSON
NIPISSING
LAUDER
BOULTER
HIMSWORTH
CHISHOLM
BOYD
PENTLAND
COLLARD
INDIAN RESERVE
HARDY
McCONKEY
BLAIR
ALGONQUIN
PROVINCIAL
PARK
WILKES
GURD
PRINGLE
BALLANTYNE
MILLS
WILSON
MACHAR
LAURIER
OSLER
BIGGAR
PARRY SOUND
GRAND TRUNK RAILWAY
80°
79°
46° 30'
Scale: 8 miles = 1 inch.
24 Miles
30 Kilometres
Preliminary Edition subject to revision

Frontispiece.

PLATE I.

Looking up Homfray channel
(June 1, 1907.)

CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; A. P. LOW, DEPUTY MINISTER

GEOLOGICAL SURVEY

R. W. BROCK, DIRECTOR.

MEMOIR No. 23

# Geology

OF THE

# Coast and Islands

BETWEEN THE

# Strait of Georgia and Queen Charlotte Sound, B.C.

BY

J. AUSTEN BANCROFT

OTTAWA

GOVERNMENT PRINTING BUREAU

1913

No. 1188

## LETTER OF TRANSMITTAL.

To

R. W. BROCK, Esq.,

Director Geological Survey,

Department of Mines,

Ottawa.

Sir,—

I beg to submit herewith a report on the geology of the coast and islands between the strait of Georgia and Queen Charlotte sour ish Columbia.

have the honour to be,

Sir

Your obedient servant,

(Signed) **J. Austen Bancroft.**

Montreal, Jan. 1, 1911.

## CONTENTS.

# ILLUSTRATIONS.

*Photographs.*

*Drawings.*



*Map.*

# Geology

OF THE

# Coast and Islands

BETWEEN THE

# Strait of Georgia and Queen Charlotte Sound

BY

**J. Austen Bancroft.**

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## INTRODUCTORY.

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### General Statement.

The area discussed in the following report embraces one of the most rugged portions of the Coast Range in British Columbia, a mountain range that is almost entirely composed of plutonic rocks which vary from granites to gabbros in composition. Numerous marine passages and fiords intersect this district in a most labyrinthine manner, and from a study of their exceptionally steep and rock-bound shores the more important geological relations of the district may be readily ascertained. These natural and well exposed sections, extending into the very heart of this mountain range, afforded an excellent opportunity for geological observations which, it is hoped, will contribute to a more complete knowledge of certain problems that are of interest to pure science, and which have an indirect but distinct economic bearing.

The study of details was limited chiefly to the geological relations of those areas where prospects were located, or where mining development had been carried on. Since the mineral deposits of economic value within this district are restricted to the stratified rocks and to their contact with the intrusive igneous mass of the Coast Range, the geological map, which has been prepared on a scale of 4 miles to 1 inch, should prove an aid to prospectors. Excellent stone for building or ornamental purposes, and materials suitable for the manufacture of bricks and cement, occur in certain localities, and these will be important assets in the future development of the region.

The present report must be considered to be a preliminary one, since areal mapping did not permit much time to be devoted to detailed study. Future field work will undoubtedly reveal many new features which were not seen, and develop many important ones which are only briefly referred to. Some of the main geological problems presented by this area and treated in this report are:- the petrography of the igneous rocks of the Coast Range, the methods by which overlying strata are invaded by so vast a mass of once molten rock, and the regional and contact metamorphism of the stratified rocks. In addition to the broad physiographic relations of the region, certain interesting types, such as fiords, hanging valleys, etc., are described and their origin discussed.

The author wishes to gratefully acknowledge his indebtedness to W. F. Robertson and H. Carmichael of the Mining Bureau of British Columbia for information concerning certain portions of the region, and for courteous assistance in procuring necessary maps. It would be difficult to mention individually the prospectors, mine owners and operators, and the men engaged in lumbering, who facilitated either by information or otherwise, the work in the field. Thanks are especially due to Messrs. A. Grant and J. Raper of Marble Bay, Texada Island; Messrs. J. S. Thompson and J. Spencer of Copper Cliff; J. Cameron and C. Lynn of Granite Bay, Valdez Island; and E. W. Wylie of Reade Island.

The work outlined in this bulletin is a continuation of that carried on, during the previous summer, in the adjacent area

to the south, by Mr. O. E. LeRoy. The methods of field work adopted were similar to those inaugurated by him. The geological mapping was confined mainly to the shore line and the auxiliary gasoline launch, "The Dawson," again proved most efficient. The fiords and channels form such an intricate network that by following the coast closely a good conception of the geology of the unexplored central parts of the islands and inter-fiord belts may be obtained. A week less than three months was spent, during the summer of 1907, in actual field operations within this area. One thousand, five hundred and forty miles of coast were examined, six hundred and eighty of this being mainland, and the remainder representing the extent of shore line presented by the numerous islands. The geological map accompanying this report is based upon the Admiralty charts, which were reduced to a scale of four miles to the inch. The charts proved to be accurate to scale in the delineation of the shore line and the topography.

In the field the writer had the advantage of the able assistance of Mr R. P. D. Graham, M.Sc., lecturer on Mineralogy in McGill University, who most efficiently applied himself to every phase of the work. The office work was executed in the Petrographical Laboratory of McGill University, and the author's most grateful thanks are due to Dr. F. D. Adams, F. R. S., for his instruction and valuable advice.

## Geographical Position and Area.

The most southern portion of the area brought within this report is the mouth of Powell river, which enters the Gulf of Georgia nearly opposite the northern end of Texada island and sixty-five miles north of the city of Vancouver. From Powell river, geological mapping was carried northward to the entrance of Kingcome inlet. The general trend of the coast is here N. 52 degrees W., corresponding to a line drawn between these points, and along such a line the distance traversed was 112 miles. The district which was examined, is enclosed by heavy dotted lines on the sketch map upon the following page. The total land area thus represented is approximately 2600 square miles, of which the islands comprise about 550 square miles.

The areas of the following islands were measured by using a planimeter:-


| Island. | Sq. Miles. | Island. | Sq. Miles. |
|---|---|---|---|
| Gilford | 98 | East Thurlow | 25 |
| South Valdes (or Quadra) | 70 | West Thurlow | 18 |
| West Redonda | 44 | East Valdes (or Maurelle) | 17 |

| | | | |
|---|---|---|---|
| North Valdes (or Sonora) | 42 | Hardwicke | 16 |
| Cracroft | 38 | Read | 15 |
| Cortez | 33 | Turnour | 15 |
| East Redonda | 26 | Harbledown | 10 |

Estimated area of other islands included .......... 90

The many waterways sheltered from the swells of the adjoining ocean, permit a ready access to this region by boat. Steamers ply regularly from Vancouver, but their course changes with the variable development of the logging industry.

## Historical.

### DISCOVERY AND EARLY EXPLORATION

The earliest knowledge that European nations possessed of this portion of the coast of British Columbia is associated with the name of a Grecian mariner, Apostolos Valerianos or Juan de Fuca, as he was called by his comrades, who was employed in exploration under the Spanish flag. During the latter part of the sixteenth century, he reported that on the west coast of North America, between the 47th and 48th parallels of latitude, he had discovered a broad arm of the sea extending into the continental mass. He claimed to have sailed within this inlet for twenty days, eventually coming forth into a broader sea, which he would have explored but for the savage nature of the Indians. Many mythical tales were abroad at that time, and possibly this story was a product of the highly imaginative mind of an old sea-dog; but if a guess it was a remarkable one, since from the description of his voyage he may have followed the sheltered passages which separate Vancouver island from the mainland.

This statement was announced at a time when the hope yet existed of discovering a channel which would connect the Atlantic and the Pacific, and thus establish a direct route for trade with the Far East. Although, in the meantime, the Hudson Bay Company had explored much of the west coast, it was not until the latter part of the eighteenth century that the interest of the British government was sufficiently aroused to collect definite information for itself. In 1778, Captain James Cook was despatched to sail along this coast from the 45th to the 65th degree of latitude, and to explore all inlets

north of the latter parallel which appeared to point toward Hudson Bay. Cook searched for the arm of the sea described by the Greek, but, failing to find it, gave the name of Cape Flattery to the projecting headland which marks its entrance at 48°5′ latitude, and sailed northward along the west coast of Vancouver island. In the account of his voyage[1] he relates that—"In this latitude geographers have placed the pretended "Strait of Juan de Fuca, but nothing of that kind presented "itself to our view, nor is it possible that any such thing "ever existed." Either the reckoning of the Greek was slightly wrong, or his imagination was, by chance, almost correct for he had stated that such a strait existed between the 47th and 48th parallels.

In the years which followed the voyage of Captain Cook several mercantile enterprises were directed toward the west coast of North America. In 1787, Captain Berkeley, an English seaman sailing under the Portuguese flag, discovered a passage immediately to the north of Cape Flattery. In the following year its existence was verified by Captain John Meares, who named it after "its original discoverer, John de Fuca." One of his boats entered this strait of Juan de Fuca, and, sailing northeastward for thirty leagues, took formal possession of the surrounding lands in the name of the King of England. They would have proceeded farther but the hostility of the natives forced them to return. Meares relates that he communicated his discovery to the Captain of "The Washington," a trader employed by a London firm, who completed the voyage through this strait, and sailing "through a sea that extends upwards of eight degrees of latitude" returned to the Pacific Ocean, probably to the north of the Queen Charlotte islands. Of this exploit Meares writes—"The track of this vessel is of great moment, as it is now completely ascertained that Nootka Sound and the parts adjacent are islands."[2] This was the first authentic voyage which demonstrated the existence of a Vancouver island.

Difficulties soon arose between England and Spain concerning trade relations and the ownership of the land upon

[1]Protlock's Voyages, page 535, Chapter on "Captain Cook's Third and Last Voyage";
Or, Cook's Voyages, Vol. II., page 173.
[2]Meares' Voyages—in 2 volumes.

this coast. In 1792, in order to settle the dispute which had arisen, Captain George Vancouver, a British naval officer, was commissioned to meet Spanish representatives in these waters. He was also instructed to explore the coast between the 35th and 60th degrees of latitude and to continue the search for an inlet which would extend toward the Atlantic. The Spanish relinquished their claims to exclusive rights of trade, and the territorial dispute was amicably settled.[1] Likewise after repeated disappointments, Vancouver abandoned the hope of ever finding a passage which would connect the Pacific and Atlantic oceans. It was Vancouver who made the first examination of the greater part of the shore line presented by the area considered in this report. He named and made preliminary surveys of many of its more important channels, inlets and islands.[2]

For sixty-five years after Vancouver made this memorable voyage, the fur trader continued to hold supreme sway upon this coast. Sir George Simpson, Governor-in-Chief of the Hudson Bay Company's territory, gives a short description of his voyages through these waters in the year 1841.[3] No further surveys were made until 1857, when a commission was appointed to determine the boundary line between Canada and the United States among the islands in the Strait of Juan de Fuca. Between the years 1857 and 1862, Captain G. H. Richards[4] conducted surveys from the entrance of Juan de Fuca strait to Bute inlet. From 1863 to 1865, Captain D. Pender surveyed the mainland coast from Bute inlet to Queen Charlotte sound. The information obtained from these early explorations has been incorporated with that derived from more recent Admiralty surveys to make a most trustworthy Pilot Book,[5] in which a detailed geographical description of the coast of British Columbia and Vancouver island may be found.

In 1793, the year after the voyage of Vancouver and twelve

[1]The Nootka Sound Controversy, by W. R. Manning, University of Chicago Press, 1905.

[2]Vancouver's Voyages. Vol. II.

[3]"An Overland Journey Round the World," during the years 1841 and 1842, by Sir Geo. Simpson, pp. 106-117; 136-145.

[4]British Columbia and Vancouver Island, by Commander R. C. Mayne, 1862.

[5]British Columbia Pilot. Third Edition, 1905.

years before the celebrated Lewis and Clark expedition in the United States, Sir Alexander MacKenzie,[1] coming from the eastward made the first recorded journey from ocean to ocean. Coming up the Peace river, he then traversed the mountain barriers of the west, arriving on the coast of Bella Coola. In 1806 Simon Fraser, while under the impression that he was going down the Columbia river, entered the waters of the Pacific by the river that now bears his name. Numerous expeditions followed, but it was in the years succeeding 1867 that a diligent search was made for passes which would be suitable for the construction of a railway.

Much attention was directed at that time to the advantages of Bute inlet as a terminus for the road,[2] and later to the possibility of connecting Vancouver island and the mainland by bridging the narrow and rapid waterways which separate them from the intervening Valdes islands.[3] Waddington gives a concise description of the valley of the Homalko river, which enters at the head of Bute inlet, and which offers the most feasible route for passage through that portion of the coast range included within this report.

### MINING DEVELOPMENTS.

Within this region mining has received but little attention, except in a limited district about Philipps Arm. In some localities near the shore numerous claims have been staked out, but in very few cases have they been developed beyond the stage of prospects. In some promising areas practically no development work has been carried on.

In the history of British Columbia, the year 1858 was signalized by the discovery of gold along the North Thompson and Fraser river. It was in the following year that the first prospecting within the area discussed by this report was recorded. At that early date, Mr. William Downie reported the presence of black sands in the alluvial deposits of the

[1] Journal of a Voyage through the North-West Continent of North America, by Sir Alexander McKenzie. First American edition, 1802; p. 246.

[2] Overland Route through British North America, by Alfred Waddington. 1868. (Longman, Green, &c., London.)
Report of Surveys, Canadian Pacific Railway, 1877, pp. 163-173.

[3] Canadian Pacific Railway Routes, by W. F. Tolmie, M.P.P., 1877, pp. 8-9. (Victoria, B.C.)

Homalko river, and veins of pyrites from Bute inlet and the vicinity of Desolation sound.[1]

Previous to the year 1896 very little prospecting had been done, but in that year the district about Philipps and Frederick arms and adjacent portions of E. Thurlow and N. Valdes islands came into prominence. A shipment was made to the Tacoma smelter which gave returns of $31.20 per ton.[2] During the following year, the absorbing attractions offered by the discovery of gold in the Klondike caused the development of these claims to be postponed. Many prospectors passed by on their way northwards to the Yukon, while some of the late arrivals stopped to investigate the mineral resources of more accessible areas along the coast. The years 1898 and 1899 were marked by great mining excitement in the Philipps Arm district, and a stimulus was given to prospecting throughout the whole area. Many claims were staked and actual mining operations were begun upon some of them. The Doratha Morton, situated west of Fanny bay on Philipps arm received the most thorough development. Extensive preparations were made for treating the ore. A Bleichert tramway, 1¼ miles long, was built to carry the ore from the mine to a Blake crusher, 10 stamp Morison High Speed mill and cyanide plant, which were erected on the shore of Fanny bay. From December 1898 to October 1899, twelve to fifteen thousand tons of ore were crushed and treated by the cyanide process, which yielded $90,000 in gold and silver bullion.[3] The mine was then closed, the unfortunate reason being that the operators had "exhausted all the ore they could "find, and in doing so found that the nature of the deposit "was such as to preclude the possibility of its turning out a "mine in the true sense of the word."[4]

Extensive work was done upon other claims, small shipments being made from some of them; but when the Doratha Morton shut down, operations were soon suspended upon the larger number of the properties in the district. Work progressed on the Blue Bells, which is situated on Frederick arm, and on the Colossus group of claims on Estero basin. On the former, a tramway to the shore was constructed, and in 1902 a trial

[1] "British Columbia and Vancouver Island," by R. C. Mayne—See Appendix, p. 447—"Report of Mr. Downie to Governor James Douglas."
[2] British Columbia Minister of Mines Report, 1895-96, p. 554.
[3] British Columbia Minister of Mines Report, 1899, pp. 800 and 806.
[4] British Columbia Minister of Mines Report, 1899, pp. 798-800.

shipment of ore was sent to Tacoma, which returned $13.50 per ton in gold and silver. When the writer visited this district in 1907 all mining operations had ceased. The extensive equipment of the Doratha Morton and the tramway of Blue Bells were in a sadly dilapidated state, shafts were full of water and some of the tunnels were impassable because of fallen rock.

In certain localities, outside of the Philipps Arm district, mining on a small scale has been carried on within this area. In 1892, the Elsie mineral claim was staked on the north shore of W. Redonda island. In the following year, 626 tons of excellent magnetite were shipped to the Oswego Iron and Steel Company's furnace in Oregon;[1] but after this shipment work ceased.

In 1906 development work began upon a number of copper claims on S. Valdes island; in the summer of 1907, this island was the centre of the only mining activity within the whole area. Rapid progress was being made upon properties at Copper Cliff, Gowlland Harbour, and in the vicinity of Granite bay. From Copper Cliff several small shipments had been made which gave satisfactory returns.

For a description of the nature and geological relations of these and other mineral properties included by this bulletin, the reader is referred to the last chapter, which deals with the economic geology of the region.

## PREVIOUS GEOLOGICAL WORK.

Earlier geological investigation of a systematic nature, within this area, is confined to the reconnaissance trip of Dr. G. M. Dawson in 1885. Embodied in his excellent "Report on the Northern Part of Vancouver Island and Adjacent Coasts,"[2] which is accompanied by a geological map on the scale of eight miles to the inch, is a description of the geology of portions of the main coast and of many of the islands which lie between Vancouver island and the mainland. The shore lines of the larger number of the islands included by the present report were examined by him, as well as the mainland between Loughborough inlet and Call creek, and in the

[1] British Columbia Minister of Mines Report, 1901, p. 1113.
[2] Ann. Rep. Can. Geol. Surv. 1886. Part B, p. 129.

vicinity of Malaspina inlet. In 1876, Dawson made a hurried trip to the head of Bute inlet, and published a short description of some of the geological features which he observed en route.[1] In the reports of the Provincial Bureau of Mines,[2] occasional brief references are made to the geology of certain districts in which mineral claims have been located. The greater part of the area, however, had not been investigated previously from a geological standpoint.

## GEOGRAPHICAL DESCRIPTION.

### The North American Cordillera in Canada.

The western border of the continent of North America is justly renowned for its mountain ranges, which in their length and breadth, although not in altitude, represent the largest mountainous area in the world. On the 49th parallel of latitude this "sea of mountains" has a width of 450 miles. In spite of the repeated protests of geologists, the term "Rocky Mountains" is even now occasionally applied to the whole of this great complex of mountain systems which lies between the prairies on the east and the Pacific Ocean on the west. In reality mountains are included within this belt which came into existence at different geological periods, which are not characterized by similarity in rock composition nor uniformity of structures, and hence have responded so differently to Nature's agents of erosion that each range or group possesses charms of scenery peculiar to itself. This wide mountainous area should be called "the North American Cordillera," or "the Cordilleran System,"[3] a name which implies that they constitute a family of mountains which are merely geographically related. From east to west the members of this Cordilleran System are:[4]

1On the Superficial Geology of British Columbia, by G. M. Dawson. Q.J.G.S. Vol. XXXIV, 1877, pp. 89-123.

2British Columbia Minister of Mines Report, 1898, pp. 1138 and 1142. British Columbia Minister of Mines Report, 1901, pp. 1105-1116.

3The Nomenclature of the North American Cordillera between the 47th and 53rd Parallels of Latitude, by R. A. Daly. The Geographical Journal, June, 1906.

4The Physical Geography and Geology of Canada, by G. M. Dawson. Handbook of Canada, (Toronto) 1897. pp. 48.

1. The Rocky Mountains.
2. The Gold Ranges.
3. The Interior Plateau.
4. The Coast Range.
5. The Vancouver System.

The Rocky mountains proper form the western boundary of the prairie region, and near the 49th parallel of latitude have an average width of 60 miles. They are of comparatively recent origin, having strata within their structures which belong to the Laramie period. The serrated nature of their crest lines, the massive pyramidal and roughly prismatic forms of certain isolated peaks, and the impressive alternation of the colours in their relatively thick component strata distinguish them from the other western mountains. On the west, the Rockies are separated from the Gold Ranges by "the Rocky Mountain trench," a narrow but most persistent depression, 800 miles in length, which is occupied by the headwaters of the Kootenay, Columbia, Fraser, Finlay, Parsnip, and Kachika rivers.

The term "Gold Ranges" as used by Dr. G. M. Dawson includes the adjacent and more complicated mountainous zone on the west side of the Rocky Mountain trench. They embrace several range units such as the Selkirk, Purcell, Columbia, Cariboo, and Omenica mountains, which have common geological structure and age but may be separated from one another by quite distinct boundaries. These are the oldest mountains in the North American Cordillera and are essentially composed of altered Pre-Cambrian sediments and granite, together with thick formations of the Cambrian and later periods, which are frequently highly metamorphosed and much contorted. Representing, as they do, the most ancient axis of elevation in the region, they have been subjected to and modified by the mountain-making stresses which have produced all of the more recent neighboring mountain systems.

Stretching between the Gold Ranges on the east and the Coast Range on the west lies an area with an average width of 100 miles, which also appeals to the traveller as being mountainous although to a less degree. On climbing to the top of one of these mountains, it is found that no sharp peaks occur but irregularly rounded, dome like, or comparatively flat

topped summits, which have so uniform an elevation that a level sky line is presented to the eye. Between the latitudes of 49° and 55°30′, where the altitudes are higher, they have an average elevation of 3500 feet. Northward towards the Yukon, the elevations are more moderate, 2000 to 2200 feet. They are not true mountains in the sense that here has been a concentration of force in the earth's crust producing elevation along a certain axis, or by the formation of domes. On the contrary, they are to be explained by a broad and gentle uplift of a once level area to the present height, and since that uplift the streams and rivers, aided greatly by the Pleistocene glacial conditions, have so deeply trenched themselves into the old surface that the interstream areas have become sufficiently prominent to be called mountains. They may well be described as mountains of circum-denudation. This region is known as the belt of Interior Plateaus, and extends from the 49th parallel of latitude far northward into Alaska, being interrupted only between the 55th and 56th degrees of latitude by the Babine and associated mountains. Although in certain parts the strata are flat, within this area the dips range through every degree of inclination to the vertical. Almost irrespective of rock composition or structure the summit levels are remarkably accordant.

## THE COAST RANGE.

West of the Interior Plateaus the rugged Coast Range borders the Pacific ocean for a distance of 900 miles, extending in a N. N. W. direction from the Fraser River valley on the south to the head of Lynn canal. It continues northward passing behind the St. Elias range of Alaska, where it gradually blends with the Interior Plateau at Lake Kluane in longitude 138°30′ near the boundary line between the Yukon territory and Alaska. In southern British Columbia these mountains maintain a width of about 100 miles, which diminishes to about 50 miles at the Lynn canal. It is not, however, easy to assign definite boundary lines to them for they shade off into Interior Plateau conditions on the east, and are closely related in their geological and physiographic development to many of the islands on the Pacific coast. The length and breadth of this range is coincident with the main portion of the great series of batholiths, composed of granites,

diorites, gabbros, etc., of remarkably uniform texture, which were intruded probably during late Jurassic time.

These vast intrusions, although very resistant to the action of the various agents of erosion, have been chiselled into most massive forms. It is impossible to delineate any axis or axes of elevation[1] for this mountainous zone, since the range has been broken into irregular groups of mountains by fiords and prominent transverse valleys. In its central portion there is a striking uniformity in the altitudes of the individual summits,[2] the most of which are about 8000 feet high in southern British Columbia and 5000 to 6000 feet in Alaska, while some occur which reach 9000 or 10,000 feet, rising as jagged peaks above the general level. On the shoreward margin of the range altitudes are more irregular, it being common to see certain peaks which are 5000 to 6000 feet high within an area where much lower altitudes predominate. The summits often have the appearance of domes, or are nearly flat on top with arching slopes which usually become more rounded and steeper as they descend below the upward limit of Pleistocene glaciation.

A considerable portion of the drainage from the Interior Plateaus makes a complete traverse of this range, and much of the excess of precipitation of the latter is thus borne toward the Pacific. Among the more important of the rivers that cross the range may be mentioned the Homalko, Klena-Klene, Bella Coola, Dean, Skeena, Nass, Stikine, and the Taku. These rivers, while in the Interior Plateaus, have comparatively broad valleys; but upon piercing the Coast Range they flow in canyons with precipitous sides. Short tributary streams with courses corresponding in general to the direction of the range enter from narrow steep-sided valleys, which head usually in a group of snow-clad mountains or in a melting glacier. In addition to these, there are a host of short and independent streams which flow directly down the western slopes of the range, often entering the sea with a final plunge. Some of these streams flow throughout the whole year, others

[1]The Geography and Geology of Alaska, by A. H. Brooks. Professional Paper U.S.G.S. No. 45, 1906. p. 28.

[2]An Expedition through the Yukon District, by C. W. Hayes. Nat. Geog. Mag., Vol. IV. 1892. p. 128.

Report on the Area of the Kamloops Map Sheet, by G. M. Dawson. Am. Rep. Can. Geol. Surv., Vol. VII. 1894. p. 10 B.

only during the wet weather and while the snow is melting in the spring.

Occasionally the rivers expand into long, narrow, deep lakes which lie like troughs locked within steep, rock-bound walls. Such lakes have, in common with the rivers and streams, two general directions — either parallel to the continental margin and Coast Range, or at right angles to this direction. Smaller lakes or tarns occupy the seats of former glaciers at higher levels.

Numerous glaciers nestle in the hollows among the more lofty mountains, while higher summits are perpetually snow-clad. In the southern part of the range, these summit glaciers are very numerous; on the 51st parallel of latitude they descend and fill up valleys, while in Alaska some even reach tide water. The glaciers of to-day are but the shrivelled modern representatives of a widespread majestic sheet of ice which filled all depressions and valleys during the Glacial Period. Everywhere the features of the landscape are dominated by evidences of most intense glacial erosion. The resistant plutonic rocks, of which this range is largely composed, have preserved in remarkable freshness the most detailed records of glacial sculpture. Polished, striated and deeply grooved surfaces, roches moutonnees, cirques, hanging and through valleys etc., have been little altered by the action of atmospheric agencies since an amelioration of the climate caused the ice to retreat. In the southern portion of the range glaciation to a height of 5000 feet,[1] and in Alaska[2] to 3200 feet, have been reported.

The mountains usually present precipitous slopes to the sea, and the declivity of the shore is as steep below sea level as it is above it. Beaches are of rare occurrence. The water is so deep that in very many places during calm weather large vessels could discharge their cargoes directly upon the shore should the slope of the mountains be sufficiently gentle to permit it. For many miles at a stretch it is impossible to find suitable anchorage, owing to the depth of water. Occasionally this difficulty may be overcome by entering a narrow cove where the bow and stern may be moored to the shore on either side.

[1]Can. Geol. Surv. Bull. No. 996 (1905), p. 25, by O. E. LeRoy.
[2]U.S.G.S. Professional Paper No. 1 (1902), p. 33, by A. H. Brooks.

The most striking characteristics of this coast are the multitude of its off-shore islands and the great irregularity of its waterways. The fiords which deeply dissect the Coast Range and larger islands are in every way similar to the intricate series of channels which separate the islands. Dawson in describing them writes:—[1] "The most remarkable feature of the coast are its fiords and passages, which, while quite "analogous to those of Scotland, Norway and Greenland, probably surpass those of any part of the world (unless it be the "last named country) in dimensions and complexity. They "also appear to differ from those of Scotland and Norway in "their narrower and more parallel-sided forms and in the "height of the walls which bound them." These fiords and channels either follow directions parallel or at right angles to the Coast Range. The most of them are straight; some are more or less winding, and the view ahead is obstructed by projecting points, which when passed seldom fail to mark the entrance to scenes of increasing grandeur. At the entrance of the inlets the mountains are lower, but they become progressively higher until the fiord reaches the heart of the Coast Range. The rugged mountain walls often rise sharply from the water as sheer cliffs which are 3000 feet or more in height.

The steeper slopes are bare or support a few stunted trees. With a lessening of the declivity, the forest growth increases until the gentler slopes and valleys are densely covered. In the southern fiords the upper limit of thick timber is about 5000 feet, which "descends northward until near Lynn C[illegible] [illegible] it is about 3000 feet."[2] Avalanches have occasionally [illegible]ft great scars on the forested slopes and in a few cases the deep water near the shore has actually been made shallow by large rock slides.

At the head of each of the fiords a brook or river enters. The larger inlets have lateral arm-like branches or small bays where the enclosing mountain walls are broken by the entrance of a stream. At the mouths of these rivers and streams

[1] Superficial Geology of British Columbia, by G. M. Dawson. Q.J.G.S. Vol. XXXIV. (1878) p. 91.

[2] The Geography and Geology of Alaska, by A. H. Brooks U.S.G.S Professional Paper 45. (1906). p. 29.

there is more or less flat land, such isolated areas being the most fertile that are to be found on the coast. These lowlands or deltas are truly river-made land, being composed of sand and mud brought down by the streams, which, when checked in their flow upon entering the sea, deposit much of the silts which they carry in suspension. The outer margin of these deltas is usually swampy and covered with bracken and grasses. During low tide wide mud flats are laid bare at the head of the larger inlets. For some distance from the shore shallow water conditions exist, but very suddenly these pass into the habitually deep water.

A few of the fiords terminate in so-called lagoons with which they are connected only during high tides. With a falling tide the lagoon is really a salt lake from which a turbulent stream enters the fiord until a rising tide produces an equilibrium of surface between the fiord and the lagoon.

In many places the channels and inlets are constricted, giving rise to very strong tidal currents, which produce dangerous whirlpools and overfalls. They are especially rapid on a falling tide, when the reservoir of water within the upper part of the fiord is seeking to maintain a level corresponding to that of the falling tide without.

## THE OFFSHORE ISLANDS.

The large number of islands upon this coast affords an almost continuous sheltered passage from the entrance of the Strait of Juan de Fuca to Skagway at the head of Lynn canal. Vancouver island and the Queen Charlotte islands, which are the most prominent, (the former in size and altitude, the latter because of their isolated position) are referred to by Dawson as "forming portions of a single axis of elevation,"[1] and as "a partly submerged mountain chain."[2] He called this most western member of the Cordilleran system "the Vancouver Range."[3] "The mountain range forming the axis of these islands lies in a north north-west, south south-east bearing, and is the northerly continuation of the Olympian

[1]The Queen Charlotte Islands, by G. M. Dawson. Report of Progress, G. S. of C., 1878-79, p. 3B.

[2]Vancouver Island and Adjacent Coasts, by G. M. Dawson. Ann. Rept., G. S. of C., 1887, p. 7B.

[3]Trans. Royal Society of Canada, Vol. VIII, Sec. 4, 1890, p. 4.

mountains of the State of Washington."[1] This Vancouver range is continued northward along the coast of Alaska as a group of mountainous islands, the western members of the Alexander archipelago. Of this archipelago Brooks writes: "The mountains of the Alexander Archipelago are properly "an extension of the St. Elias Range, but as they are separ-"ated from the mainland, and divided into different groups by "broad tidal waterways, they can hardly be included under the same name."[2] These islands are so arranged that lengthwise they are parallel to "the trend lines" of the other members of th[illegible]. They express the probable continuity [illegible] which formerly bridged all the gaps existing today between the Olympian mountains of Washington state and the St. Elias range of Alaska.

Vancouver, which is the largest island on the Pacific coast of America, has a length of 280 miles, and an average width of about 50 miles. Its northern and southern extremities are comparatively low, and on the east a border of flat land, varying from two to ten miles in width, extends as far north as the Seymour narrows, about 140 miles from Victoria. With the exception of much smaller areas at the mouths of rivers, and a few open glades in certain valleys, the island is mountainous. "The highest mountain, Victoria peak, attains "an elevation of 7484 feet, while there is a considerable "mountainous area in the centre of the island which exceeds 2000 feet in average altitude."[3] On the west the coast line is broken by fiords, which penetrate far into the rugged interior. On the east, although a number of sheltered bays do afford anchorage, the shore presents a remarkably smooth outline.

One hundred and thirty miles north of Vancouver island, the Queen Charlotte islands form a triangular shaped group with an acute apex pointing southwards. The group, from north to south, consists of three large islands, Prevost, Moresby, and Graham, and associated with these are many smaller ones. Their extreme length is 155 miles, and on Graham

[1]Memorandum on the Queen Charlotte Islands, by G. M. Dawson. Canadian Pacific Railway Report, Appendix No. 9, p. 139.

[2]Geography and Geology of Alaska, by A. H. Brooks. Professional Paper U.S.G.S., No. 45, 1906, p. 28.

[3]Superficial Geology of British Columbia, by G. M. Dawson, Q.J.G.S., Vol. XXXIV, 1878, p. 92.

island they have a maximum width of fifty-two miles. "The "highest and most rugged part of the mountainous axis of "the islands is found in latitude 52 30', where many peaks "bear considerable patches of perennial snow, and rise to alti "tudes probably surpassing 5000 feet."[1] In contrast with Vancouver island, the eastern and northern as well as the western shores are deeply dissected by fiords.

The Queen Charlotte islands are separated from those that closely fringe the mainland by the open waters of Hecate strait, which varies from 35 to 80 miles in width. The passage between Vancouver island and the main coast has a maximum width of 50 miles: but a multitude of islands are situated within this intervening space. Those islands which follow the mainland most closely are related in every way to to the Coast Range. Those which are farthest offshore combine geological and topographical features of both the Vancouver and Coast Ranges.

There is much variation in the size and altitude of this vast archipelago. Some of them are tiny islets, bearing a thin soil and clothed with profuse vegetation; others are merely rocks with a smooth and rounded appearance, which do not rise more than a few feet above the high tide water. The majority, however, are mountainous, with bold and rugged shores, which frequently plunge into deep water without any beach. A few of the islands reach elevations between 3000 and 5000 feet. There is no marked regularity in their distribution. North of Vancouver island their longer axis usually corresponds with the trend of the Coast Range; but between Vancouver island and the mainland their length often lies directly transverse to this direction. The shore lines of many of them are extremely irregular, being broken by bays and fiords.

In Puget sound,[2] in the northern part of the Gulf of Georgia, and in Queen Charlotte sound there are a few islands which are remarkably different from the types just described. They are composed of stratified and unstratified clays, which

[1]The Queen Charlotte Islands, by G. M. Dawson. Report of Progress, G. S. of C., 1878-79, p. 3B.

[2]The Drift Phenomena of Puget Sound, by Bailey Willis. Bull. Geol. Soc. of America, Vol. IX, 1898, pp. 111-162.

rise from 100 to 200 feet above sea level, and, in striking contrast to their mountainous neighbours, their shores are surrounded by dangerous shoals.

## General Character of the District.

### TOPOGRAPHY.

The preceding description fulfils a twofold object. It makes plain the relationship between the various members of the Cordilleran family, thus giving a proper setting to the area dealt with by this report; and it portrays those topographic features which characterize this area in common with all other parts of the Pacific slope of the Coast Range and the adjacent islands.

Within this district the Coast Range intrusions have extended westward so that they impinge most closely upon Vancouver island, and, in consequence, the mountainous topography of the greater number of the islands, as well as the mainland, has been sculptured from massive plutonic rocks. For this reason, the inlets or fiords penetrate farther into this mountainous mass than the position of their entrances and their respective lengths would at first suggest. It also explains why the mountains are higher at the entrances of some of these fiords than those in a corresponding position to the north or to the south. The many inlets and passages, some of which are called arms, creeks, sounds, harbours, and channels, have broken the western slopes of the Coast Range into a ragged fringe of peninsulas and islands which repeat the contours of the mountainous topographic unit from which they have been carved.

Upon the mainland, the four most prominent inlets, Toba, Bute, Loughborough, and Knight, have lengths of eighteen, forty, seventeen, and sixty miles respectively, the latter, in reality, extending for twenty miles farther westward through the islands. In the grandeur of their scenery, Bute, Knight and Toba inlets surpass all the others within this area, and must rival in their magnificence all examples of the fiord type in the world These chasms, or deep trenches, with widths varying from three-fourths to two miles, are hemmed in by

precipitous walls which culminate in mountains from 3000 to 8000 feet high. Toba is a short inlet, but so much of the Coast Range has been dissected into islands which lie directly in front of its entrance, that its course lies among mountains with altitudes almost as high as those which characterize the heart of this range. At the very entrance of Bute inlet altitudes of 3000—5000 feet prevail, while the quadrant-shaped outline of Estero peak attains to 6055 feet. As one ascends to the head of this fiord, the scenery ever increases in grandeur, until summits of 6000 to 8000 feet appear on every hand. One of the Needle peaks (8145 ft.) is the highest altitude that has been determined in this district. In passing up Knight inlet, the elevations of the enclosing mountains are at first lower, but beyond Glendale cove its winding course affords rapidly changing scenes, which are even more impressive than those in Bute. Within Loughborough inlet the mountains are lower, a few snow-clad summits being visible at some distance inland from its head. From Powell inlet to Theodosia arm, from Topaze harbour inland toward Glendale cove and along the coast to beyond Port Neville, and in the vicinity of the Wishart peninsula, the mountains, in general, are the lowest to be found along the main shore. With the exception of those portions of Blinkinsop bay, Topaze harbour and Port Neville, which are bordered by sandy terraces, and the lowlands which mark the entrance of streams, the slopes are not less steep, and occasionally mountains rise to altitudes of two to over three thousand feet. Bald mountain (2925 ft.) on Simoom sound is a remarkable isolated dome of grano-diorite, being so conspicuous that the Indians point to it as an example of a smoke-mountain or volcano. A large valley extends from Boughey bay across the peninsula which separates it from Johnstone strait, and a low pass also exists between this bay and Port Neville. The water parting is also low between the streams which enter Tsa-ko-nu cove on Knight inlet, and Cutter creek on Chatham channel. The delta lands at the heads of the inlets and bays comprise the largest flat areas in the mainland belt. The delta of the Homalko river, at the head of Bute inlet, and that of the Klena-Klene, at the head of Knight, are estimated to include 2500 and 3000 acres respectively, while farther up these rivers rich bottom lands are reported. Seaward, these

areas of river-made land extend as mud flats during low tide, and their margins descend so steeply into deep water that the bow of a boat may be resting upon the mud while the stern is afloat in several fathoms

Within all the fiords, the projecting points or spurs usually have the more gentle slopes, but generally the descent from the water's edge is very steep. In some places sheer cliffs rise for several hundreds of feet, and some of the most majestic peaks are not more than two to three miles from the shore. For considerable distances it is impossible to gain a foothold for a landing. Landslides have been frequent, and occasionally have increased the declivity of slope, and at the same time have caused the deep water near the shore to become shallow. the apices of the cones of fallen rock fragments sometimes projecting above sea level along the shore line. In a few instances turbulent streams, as at Rubble point near the head of Knight inlet, have swept down sufficient rock rubbish to build up alluvial cones, which are similar in appearance to those produced by the rock slides. On the northern side of Knight inlet, near Grave point, a large rockslide has taken place, in which a portion of a mountain from shore to summit has toppled over into the water. The movement took place along joint planes, and has resulted in a precipice which was estimated to be over 2000 feet in height, a most imposing and almost perpendicular cliff of massive granite. Even now when the wind blows hard, small jointed blocks are loosened from the heights and rattle down upon the pile of rubbish already accumulated. So near are the high mountains to the shores of the inlets, that within the larger fiords the lateral range of vision is very limited. Occasionally, however, there is a break in the steep walls, a small arm of the sea extends inward, terminating in a few acres of delta land; the depression in the sky line persists inland, marking the direction assumed by the valley of the stream which built the delta; and then a vista is gained of those mountains in the background which otherwise would have been concealed from view. Knight inlet possesses six of these lateral embayments, of which Wah-shi-las bay may be mentioned as an example. (See Plate II.)

PLATE II.

Wah-shi-las bay, Knight inlet.

Perpetual snow bedecks the higher levels (usually above 5000 feet), or reposes in sheltered nooks where it has often been cast to lower slopes by avalanches. In the upper reaches of Bute and Knight inlets, glaciers and patches of ice occupy some of the hollows and valleys among the higher mountains. The largest were seen at the head of the former, and in the higher valleys above Cascade point and Wah-shi-las bay in the latter inlet. From Bear bay on Bute inlet one may count seven small glaciers. The mountains, in general, present the appearance of having been profoundly glaciated to altitudes ranging between 4000 and 5500 feet, while the highest summits are rugged and often have very sharp profiles. Well developed cirques of various dimensions are numerous, these vacated homes of summit-glaciers occasionally imparting sharpened summits to otherwise rounded mountain forms. Within some of them, patches of ice, which are mere remnants of the glaciers which once filled them, still remain. A few side-valleys debouche into the fiords at varying heights above sea-level, the three most imposing examples that were noted occurring just beyond Boyd point on the northern shore of Bute inlet, just beyond Protection point, and at Cascade point on Knight inlet. The general U shape of the fiord valleys, the truncated spurs, through valleys, the slope and crag structure exhibited by some of the slopes and the concave outlines of others, the cirque-like heads of the fiords and bays, roche moutonnées, and the flowing outlines of the lower mountains may be enumerated as topographic characteristics which have been bequeathed to this region by the former glacial ice-sheet.

The topography of the islands resembles in every way that of the mainland. Most of them are mountainous with bold shores which are in some places so steep as to be inaccessible. A few reach elevations between 3000 and 5000 feet. The highest point is on East Redonda island, which lies opposite to the entrance to Toba inlet, where Mt. Adenbroke lies 5,120 feet above the sea. Raza, a neighbouring island with a striking pyramidal appearance, has an area of about five square miles and rises to 3,020 feet in altitude. Gilford island, with an area of ninety-eight square miles, is the largest member of the archipelago and presents a mountainous mass of very irregular outline. In the eastern part of the island the

mountains are highest, the lofty Mt. Read being 4,820 feet above sea-level, while Mt. Hulton, within less than one mile and a half from the shore of Tribune channel, is 3,980 feet high.

South of Nodales channel, the islands are elongated in a direction trending north and south; north of this channel they assume an east and west direction. It was once believed that what are now known to be the three Valdes islands were but a single insular unit. They so nearly close the passage between Vancouver island and the mainland that only three narrow channels, having a total minimum width of about one mile and three-fourths, intervene. Of this group, S. Valdes or Quadra island is the least rugged. Several lakes occur inland which lie in low, irregular, rocky basins. From Granite bay across to Open bay quite a broad tract of inhabitable land extends parallel with a range of mountains immediately to the south. Sonora island, in contrast, is very rugged, rising from Cardero channel to altitudes of over 3,000 feet. In its southern part, West Redonda Island is almost cut in two by a large lake which extends nearly from Marylebone inlet to Refuge cove, sending at least one arm to the north. Cortez island is likewise nearly separated into three islands by Von Donop creek and a long shallow salt lagoon; the southern part is characterized by comparatively low elevations, while the long peninsula extending northward resembles a rias-mountain range.

Many of the islands north of Nodales channel have triangular outlines, with their most acute angles truncated and pointing westward. Elevations are highest upon their eastern ends and gradually descend westward. Cracroft island has two easy passes across it, one from Port Harvey to Lagoon cove, along a line of small lagoons which the Indians connected by constructing a small canal through which they could float their canoes during a high tide; and a second from Forward bay to a bay opposite Klaotsis island. North of Harbledown and Turnour islands, myriads of small islands are congregated in Queen Charlotte sound, protecting the western shores of Gilford island from the Pacific ocean swells which roll into the Sound. Within this area of sixty-three square miles, five hundred and seventy islands are recorded on the chart. The

greater number of them are covered with trees or more lowly vegetation. Some of them are bare rocks, so low that they are continually awash during a storm; others rise to remarkably high elevations when their basal area is considered. Many of them display, to a most surprising degree, deep glacial groovings and striations, and some of them quite perfect roche moutonnée outlines. Although no snow fields or glaciers are now to be found upon any of the islands covered by this report, evidences of former glaciation dominate every feature.

In the northern part of the Gulf of Georgia, four islands. Harwood, Savary, Hernando, and Mary, and the southern extremities of South Valdes and Cortez islands are of a very different character from the mountainous and rocky islands just described. They are composed almost entirely of drift deposits, boulder clay with stratified sands and gravels, which at no point rise to more than 200 feet above the sea. The areas included in these comparatively flat lands are 1900, 1200, 2200, 2200, 2700, and 2300 acres respectively. The southern shore of Savary is exceptionally steep, the exposed bank showing most clearly the relation between the boulder clay and the well stratified deposits. The southern point of Harwood island, the extreme east end of Savary, and Hidalgo point on Hernando island exhibit the nature of the rocky base upon which these unconsolidated materials rest. When the dense forest growth which covers the larger part of these islands is removed, valuable land will be afforded for agriculture and pasturage. At present, sheep are pastured on Hernando and Mary islands. After the timber is cut, care must be taken to provide the more sandy tracts with some lowly form of vegetation, such as grasses, or the wind will rapidly diminish the acreage by a slow yet steady removal of the otherwise loose sand into the sea. With the exception of the rocky points mentioned, their shores are, as a rule, low and dangerous to navigation, for on the shallow sea floor surrounding these islands many large boulders are irregularly distributed. During low tide, some of these boulders are exposed upon the wide expanses of beach which are uncovered in some places; others project above the water to a considerable distance as a warning which the mariner in these waters

seldom expects, because deep water conditions usually exist close to the shores. A long narrow reef of boulders extends southward from Mary island for a distance of a mile. Somewhat analogous to these islands are the low sandy terraces, not more than sixty feet high, which border Squirrel cove on Cortez island, the southwestern shore of Hardwicke island, the southeastern shore of West Thurlow island, and the vicinity of Port Neville and Blinkinsop bay on the mainland. A terrace, 300 feet in height, may be seen at a short distance from the Powell river.

The bays and coves of the island shores correspond to the lateral bays of the fiords on the mainland. The eastern shores of those islands which are directly adjacent to the main coast are smooth in outline: Wa-ka-na bay on Gilford island being the only exception to this rule. In contrast, the western and most pointed ends of some of the islands have a frayed appearance, owing to the re-entrant nature of the shore line. On Cortez, Cracroft, and the west side of Gilford islands, some of the bays head in shallow salt lagoons.

The channels between the islands repeat the characteristic features of the mainland fiords. They are singularly free from shoals. The excessive depth of water near the shore makes it difficult to find anchorage with a reasonable length of cable. In most instances, the soundings recorded on the chart do not represent the total depth. The depths of the channels ordinarily used by traffic have been quite thoroughly explored, but from the entrance nearly to the head of Bute inlet, for example, they never reached bottom with forty-seven fathoms of line, except in Orford bay. Sufficient soundings have been made to demonstrate that the bottom has many irregularities and that in some of the fiords, at least, the water becomes shallower at the entrance. Call creek, quite near its head, has a depth of over one hundred fathoms; at its entrance, fifty fathoms; and the neighbouring channels lying immediately in front of its mouth have a depth of twenty-two fathoms. As one would expect, the chart shows many irregularities of that portion of the sea bottom which bears the vast archipelago of small islands in Queen Charlotte sound, but even here Arrow passage extends through them, maintaining a persistent depth of over forty fathoms. From

Plate III.

Seymour Narrows.
(Photo taken August [illegible])

Seymour narrows, along Johnstone strait, the lack of uniformity among the soundings is most noticeable; those of one hundred or more fathoms predominating, with the deepest reaching to one hundred and seventy.

Where the channels are narrow, the tides flow swiftly, often developing heavy overfalls and whirlpools. The tide enters the passage between Vancouver island and the mainland, both from the north through Queen Charlotte sound and from the south through the Strait of Juan de Fuca and the Gulf of Georgia. These tides meet in the northern part of the gulf, between Mitlenatch island and Cape Mudge, producing strong tidal rips which, when a fresh wind is blowing, are converted into a heavy choppy sea, in which the crest of each wave is broken into a chaos of sharp pinnacles. The tide from the north has to pass through the constricted channels, Seymour narrows, Surge narrows, the Hole-in-the-Wall and Euklataw rapids, which isolate and dissect the wedge-shaped Valdes islands. Most of the steamers pass through Seymour narrows on the Vancouver island side, which in one place is contracted to 700 yards. The velocity of the current which passes through this constriction is variable with the tide; usually it ranges between seven and nine knots but during some spring tides, when the maximum rise of fourteen feet takes place, it attains a rate of from ten to twelve knots.[1] In mid-channel, Ripple Rock rises to within two fathoms of the surface, and over this spot the water swirls in deep eddies. In watching the tide rushing through this narrow channel "with such immense impetuosity as to produce the appearance of falls considerably high,"[2] an observer can well appreciate the manner in which a small vessel of insufficient power would pass "reeling wildly out into the gulf, the mere sport of the whirlpools."[3] In several passages north of these, somewhat similar phenomena may be seen, although the tide does not run with so great velocity.

## DRAINAGE.

Already mention has been made of the fact that the fiords head in low delta lands, the sands and muds of which have

[1]British Columbia Pilot, 1905, p. 248.
[2]Vancouver's Voyages, Vol. II, p. 259.
[3]Simpson's Journey Round the World during the years 1841-42, p. 138.

been deposited by streams whose valleys extend far into the mountains. The walls of these valleys display no change in character, and the absence of sea water is the only feature in which they differ from the fiords themselves. In general, the Coast Range forms an efficient watershed, separating the streams which enter these arms of the sea from those which drain into the rivers of the Interior Plateau. Within this district, however, two rivers, the Homalko in Bute inlet and the Klena-Klene in Knight inlet, have their head waters in the interior plateau, and pass completely through this Range. Two rivers discharge into the heads of some of the fiords; into Bute inlet, the Homalko and the Southgate rivers, the latter flowing from the southeast; into Loughborough inlet, the East and West rivers; and into Knight inlet, the Klena-Klene and the Ah-ash-ma-aki. All of these, in common with the smaller streams at the heads of the other fiords, flow from U shaped valleys across low-grade deltas.

The Homalko river, which is the longest, may be considered as typical. While crossing the outer part of the delta, the width of its valley is about two miles. It is a rapid, muddy stream, about 300 feet in width, but, in places, it assumes a braided character, spreading out to over 1000 feet. A sand bar extends across its mouth, which has from one to two feet of water over it at low tide; within this obstruction the water deepens to one and three fathoms.[1] A long, narrow side-wheel steamer, belonging to a lumber company, is now plying on the river, which is reported to be navigable for boats and small steamers for a distance of about twenty miles. Waddington writes as follows:—[2] "The valley of the Homalko "river presents a deep cut or fissure through the Coast Range, "varying from three miles to less than a quarter of a mile in "width; is 84 miles in length, and rises imperceptibly to a "height of 2400 feet or more, where it enters the plain beyond "the mountains. For the first 31 miles up to the canyon or "defile, the bed of the valley is composed of diluvial soil, con-"sisting of a sandy clay or loam, and forming a hard dry "bottom. The canyon itself is exactly one mile and a quarter "in length. Beyond the canyon, the valley again forms and "opens for about six miles. The river after this is again

[1]British Columbia Pilot, 1905, p. 238.

[2]Overland Route through British North America, by Alfred Waddington, 1868.

confined to a narrow bed for six miles, when the valley once more opens and recovers its flat and level aspect, which it maintains up to the plain.

"The rise in the valley though apparently uniform presents considerable variations. Thus, the canyon presents a rise in 30½ miles of only 860 feet above the sea. The river then becomes much more rapid, and gives for the next thirteen miles an ascent probably of 780 feet, after which, for forty miles up to Fifth Lake, the rise diminishes to 630 feet, beyond which there is a sharp ascent for a couple of miles more of say 150 feet when the summit or watershed is attained. The above figures must, of course, be considered as only approximate."

The river receives many rapid tributaries which flow from glaciers, some of which descend almost to the main river. "Some of these streams have brought down large quantities of debris from the mountains, raising their beds across the Homalko valley considerably higher than the land a few hundred feet from each side of the stream." Thirty-nine miles from its mouth the river divides into east and west branches, of which Waddington followed the west. The eastern branch extends for 55 miles from the junction, at an altitude of 3,500 feet, taking its rise in a chain of lakes. The largest of these lakes is Tatlayaco, 15 miles long, whose outlet is 33 miles from the source of the river, and is 2,712 feet above the sea. Upon leaving this lake, the river is one hundred feet wide, and for fifteen miles descends at a rate of 1 foot in 100, when it flows rapidly through a narrow defile to the junction.[1]

The preceding description shows that the main streams have approximated to a stage of maturity. The extension of the valley-tracts so far into the mountains and the restriction of lakes and rapids to the upper reaches are, at least, indicative of a well-developed drainage.

The Klena-Klene river flows swiftly and seems to carry more mud in suspension than the Homalko. While passing up Knight inlet, the waters were first noticed to be slightly turbid at a distance of 45 miles from its head, and they became more milky in appearance as the head of the inlet was ap-

[1]Information here derived from Report of Surveys, Canadian Pacific Railway, 1877, pp. 163, 165, 169-170.

proached. This river flows across its delta in two main distributaries in which there are a few low islets, composed, as are the beds of the river channels, of gravel and coarse pebbles which have been swept down the valley. The river flows swiftly, but it is reported that small boats can pass up it for a distance of eight or nine miles. Twelve miles from its mouth it is said to fork, and a large glacier, which occupies the valley of the west branch, descends into the main river. The Ah-osh-ma-aki, the second river which enters the head of Knight inlet, flows from the S. E., discharging through a valley which is about a mile in width. In its lower course, it follows the left side of the valley; it flows more swiftly and its waters are not so muddy as those of the Klena-Klene.

The other rivers which debouche into the heads of the fiords are smaller, but present similar gradients, the relative inland extension of the valley-tract being dependent upon the size of the stream. For example, the West river, at the end of Loughborough inlet, is navigable for small boats to a distance of three miles from its mouth, when it is reported to become more rapid and shallow.

At least four types of lateral streams enter these fiords. Those which discharge into the side bays are quite similar to the larger rivers already described. Their mountain-tracts are not so far removed from the sea and, in some cases at least, they flow in V shaped notches which have been incised within U shaped valleys. The rivers which enter Orford bay on Bute inlet, and Salmon bay on Toba inlet, may be cited as examples. Besides these, there is a much younger series of streams occupying V shaped valleys and descending the slopes in a succession of foaming rapids and cataracts; these shade over into those possessing still less distinct valleys and an intermittent flow. A few streams enter from valleys the mouths of which are situated at various levels above the deep water in the fiords, a feature for which Gilbert proposed the name "hanging valley." From the mouths of these high valleys, the water descends either in a series of rapids, or by making one grand final plunge of several hundred feet directly into the fiord, as at Cascade point on Knight inlet. This coast is remarkably picturesque during wet weather and especially in the months of May and June, when the winter's

snow on the higher levels is melting; then myriads of boisterous rivulets, quite often leaping a thousand feet at a time, vie with one another in their race for the sea. This fourth series of streams have no definite valleys, but seek the most direct and easy routes, often following the paths prepared by avalanches. In the springtime, the courses which they assume and their term of life are dependent quite largely upon the position of the receding snow line. Early in the month of June, 1792, Vancouver[1] recorded the following description of the Coast Range in the vicinity of Bute Inlet:-......"the "stupendous snowy barrier rising from the sea abruptly to "the clouds, from whose frigid summit the dissolving snow "in foaming torrents rushed down the sides and chasms of "its rugged surface, exhibiting altogether a sublime though "gloomy spectacle which animated nature seemed to have "deserted. Not a bird nor a living creature was to be seen "and the roaring of the falling cataracts in every direction "precluded their being heard had any been in our neighbour-"hood."

Small lakes are fairly numerous, both upon the mainland and on some of the islands within this district. A stream which enters Glendale cove, on Knight inlet, flows from Tom Browne lake, which is about one mile distant. This lake, which has never been surveyed, is reported to be about five miles long, extending toward the head of Topaze harbour; it is narrow and long, being imprisoned between rocky shores, and presenting an appearance of what one might call a fresh-water fiord. A few hundred feet from its outlet, the stream falls over a rocky sill about ten feet high.

## THE FIORDS AND ISLANDS.

The word "fjord" was first applied by the Norwegians to the long, narrow and deep inlets or arms of the sea which impart an extreme irregularity of outline to the west coast of their native land. When it was found that this physiographic type repeats itself upon many other shores (as in New Zealand, Patagonia, British Columbia and Southern Alaska, Labrador, Baffin Land, Greenland, Iceland, and Scotland), this term was borrowed from Norway and given a position of general signifi-

[1]Vancouver's Voyages, Vol. II, p. 195.

cance. The origin of fiords is a subject that has aroused considerable discussion in geological literature, and has been productive of divergence of opinion. Some of the earlier writers resorted to downwarping or faulting in order to explain the depressions, "rents" or splits which the fiords now occupy. Modern study has led to the belief that the ramifications of the fiords delineate with approximate exactitude the lines of drainage which were developed upon a pre-existing land surface: that these depressions are largely the result of the erosion of pre-glacial streams, the courses of whose valleys were determined by the regional trend and slope, variable resistance to erosion of rocks and their structures, prevailing joint systems, lines of faulting or sags, in the initially uplifted land area. Many fiords are known to follow lines of faulting, but the faults may be considered as lines of weakness sought by pre-glacial streams in the sculpture of their valleys, and only indirectly explain the directions assumed by the submergence which has formed the fiords. It is the presence of the sea within these valleys that has created the major differences in opinion. Some writers explain the fiords as a direct and natural result of a subsidence of the land margin, in which the lower portions of the valleys have been drowned, and the hill and mountain tops converted into a fringe of islands and peninsulas. The exponents of this explanation admit that the slopes of the preglacial land surface have been smoothed and rounded by the ice-flood of the recent glacial period, but they deny that ice has the power to scoop out rock basins. Other observers claim that the prolonged scouring and grinding action of the glacial ice which followed these valleys has not only profoundly altered the enclosing slopes, but has excavated rock-basins in their lower ends to depths below sea-level; that, upon the recession of the ice, the sea followed the retreating margins of the glaciers in neighbouring valleys to distances inland corresponding to the variable lengths of such eroded basins.

Intimately connected with fiords are the long and narrow lakes in glaciated countries which occupy trough-like depressions, some of which are rock-basins of great depth. The form of the fiord basin is similar to that of these glacial lakes. In fact, the only difference which exists between cer-

tain fiords and some of these lakes is to be found in the taste of the water. It is a remarkable coincidence that the distribution of such lakes and shores fretted by fiords is restricted to regions which have been heavily glaciated. Moreover, the geological records along fiorded shores almost always demonstrate Post-Glacial uplift, although it must be remembered that subsidence, or "a positive displacement of the strand line," as it has been called by Suess,[1] usually leaves no immediate records. In discussing the origin of these lakes and fiords, a downward crustal movement is advanced as the cause by some, who base their argument largely upon an analogy with recognized "drowned coasts," and a glacial cause is advanced by others. The latter explanation, which regards these lakes as glacially excavated rock basins, within pre-existing valleys, and the fiords as similar basins which the sea has entered after the ice melted away, is attracting a constantly increasing number of adherents. It may be of interest to record the opinions of some of the observers in other fields.

As a result of his study of the larger lakes of Switzerland, Ramsay, in 1862, concluded:— ..."they did not exist as "lakes after the disappearance of the glacier." "The "lake basins could only, I believe, have been scooped out by "the true continental ice like that of Greenland."[2] Lubbock[3] in his "Scenery of Switzerland" agrees with Heim in his suggestion that:— "The mountain mass thus concentrated on "a comparatively small area would, from its enormous weight, "tend to sink somewhat into the softer magma below, which "of course would have had in this respect the same effect as "if the country had risen. The result would be to dam up "the rivers and fill the valleys. In fact, speaking generally, "the great Swiss lakes are drowned river valleys." Heim seems to have demonstrated, from a study of the terraces about some of these lakes, that there has been considerable post-glacial warping. Penck, on the other hand, follows and makes more convincing the contentions of Ramsay.

In this "Scenery of Scotland," Sir Archibald Geikie contrasts the origin of lakes and fiords as follows:—. . . .

[1]The Face of the Earth, by E. Suess (translated by Sollas), Vol. II, p. 24.

[2]Glacial Erosion of Lakes, by A. C. Ramsay, Q.J.G.S., Vol. XVIII, 1862, pp. 192 and 202.

[3]The Scenery of Switzerland, by Sir John Lubbock, 1896, p. 163.

"to my own mind the view that these lakes have been mainly "eroded by land ice seems most in accord with the evidence "and to involve the smallest number of difficulties and con- "tradictions."[1] The fiords are "old glens that have been "submerged beneath the sea. They prove that the west side "of the island has subsided in a comparatively recent geologi- "cal period and that the tides now ebb and flow where of old "there was the murmur of brooks and waterfalls."[2]

Helland[3] was an ardent supporter of the view that fiords are of glacial origin. Concerning Norway, he says: "The "land is formed of rocks different in composition and origin, "for which reason the country from the first has had a very "uneven surface. On this thousands of rills and rivers "began their work, and, previous to the Glacial Epoch, "eroded valleys more or less deep and broad. During it "the glaciers followed, on the whole, the course of these "enlarging and shaping them." Hansen,[4] who agrees with him, states that "it is impossible to deny that such enormous quantities of drift have been removed from Norway ... "Quaternary time that we must look for marks of denudation "of quite as great degree as our lakes and fiords."

Of special interest is the valuable contribution made by Andrews,[5] who had "not so much as seen a region of former or present intense glaciation" until he made a study of the New Zealand fiords. After describing existing topographic features, and contrasting the land forms produced by streams and ice-flood erosion, he writes: "Subsidence has "often been advanced to explain the depth of fiord waters. "Against this the author would strongly protest, unless sup- "ported by observation. . . . . Subsidence post-dating "glacial times there has certainly been in New Zealand, but "apparently nothing approaching the depths required to "sink these old ice channel floors 2000 feet or more below the "sea-surface . . . . . Rock-basin excavation along old "stream channels below base level during periods of maximum

[1]The Scenery of Scotland, by Sir A[illegible]
[2]Ibid, p. 182.
[3]On the Fiords, Lakes and Cirques in Norway and Greenland[illegible] Helland, Q.J.G.S., Vol. XXXIII, 18[illegible]
[4]The Glacial Succession in Norway[illegible] Geology, Vol. II, 1894, p. 123.
[5]The New Zealand Sound Basins[illegible] ogy, Vol. XIV, 1906, pp. 22-54.

"ice-flood, combined with slight later drowning, is a sufficient "explanation."

In his recent report on the Geology of the Queenstown subdivision in New Zealand, Park[1] states that:—"Lakes "Luna, Hayes, Moke and Johnson are only exaggerated rock-"tarns scooped out by ice in the floor of the valleys in which "they lie. That some of them lie in the track of faults "is not the cause of their formation, although the faults "doubtless played a part in determining the situation and "direction of the [illegible] glacial valleys in which these lakelets "lie."

In discussing the general subject of glacial erosion, Davis,[2] who has elaborated its possibilities more than any other writer referred to, says:—"If liberal measures of "glacial erosion and glacial time are allowed, no depression "of glaciated coasts since pre-glacial time is needed to account "for the peculiar features of fiords. The glacial channels "may have been simply invaded by the sea, as the ice melted "away, without any true submergence." In his excellent treatise on "The Sculpture of Mountains by Glaciers,"[3] he closes with the following sentence:—"The sculpture of moun-"tains by glaciers is indeed now proved by so many facts, "widely and yet systematically distributed, that it savours "of extreme conservatism any longer to deny the efficacy of "glacial erosion."

[illegible] evidence have been advanced by Gilbert [illegible] Tarr, in writing upon the fiords of Alaska, to deduce that glacial erosion has been such a potent factor in their development that it constitutes in itself a sufficient explanation for the recent invasion of the pre-glacial valleys by the sea. It [illegible] importance to present an analytical [illegible] features, large and small, which characterize the more southerly fiords, described by this report, in order to ascertain if they bear the same ear-marks as those in [illegible]

[1] [illegible] on, Bull. No. 7, New Zealand [illegible]

[2] [illegible] Erosion [illegible] Switzerland and Norway, by W. M. Davis, [illegible] Bost. [illegible] XXIX, [illegible]

[3] [illegible] 1906, Feb. 1906.

Most of the data included in this description was obtained at low levels, but the few ascents which were made demonstrated that the ice-sheet exceeded Dawson's[1] estimate of 3000 feet. Many of the slopes and summits, as seen from the fiords, present a glaciated appearance to 4500 feet, and it is difficult to estimate the amount of ice which must have stood above this level in order to impart characteristic glaciated forms to them. It is not improbable that the glaciers of adjacent mainland fiords varied somewhat in thickness. In the area to the south LeRoy[2] estimates the Jervis inlet tributary to have been at least 5000 feet thick. A thickness of 5000 feet of ice would exert a pressure of about 130 tons per square foot. It was under this great pressure that the rock-fragments, which were frozen within the lower surface of the ice, acted as a powerful abrasive to produce the forms which are to-day referred to as *glaciated*.

A description will here be given of those features, large and small, which may be attributed to the eroding action of glacial ice within this region:—

(1) *Striations, Grooves and Lunoid Furrows.* The slowly creeping ice masses, which filled these fiords to an altitude of 4000 feet and more above the present sea-level, inscribed remarkably distinct records upon the walls and floors over which they moved. In some places the ice acted like sandpaper, in others like a heavy plough. Over considerable areas its trails are faint, or have been effaced by exposure to the weather since the retreat of the ice; but upon many of the surfaces of the massive granite "the writing upon the wall" is as fresh as if it had been executed yesterday. Especially distinct are the striations and grooves in certain patches along the zone which is laid bare during a low tide, while high up on some of the mountain slopes near the shore, grooves may be distinctly seen from the water. The polishing and smoothing effects of the ice are exceptionally clear upon some of the rounded surfaces, from which the ice has removed even granular asperities. Every gradation may be found, from mere scratches to deep and broad grooves in which a man may effectually conceal himself from a lateral view. Some of the deepest trough-like grooves were noticed at the mouth

[1]Trans. Roy. Soc. of Canada, Vol. VIII, Sect. IV, p. 34, 1890.
[2]Can. Geol. Surv. Report No. 996, 1908, p. [illegible]

(a) Entrance to Bute inlet showing upward limit of glaciation [illegible] ... [illegible] on the left.

(b) Glacial groove in Loughborough inlet.

of Southgate river at the head of Bute inlet, in many localities in Knight inlet, but especially upon some of the islands in Queen Charlotte sound. Hanson island, some of the smaller islands in the channel of Knight inlet (near its entrance); and others in the vicinity of Eden island have deeply corrugated surfaces in certain parts, owing to the development of profound parallel grooves.

On the walls of the fiords, the striae and grooves are usually arranged horizontally, extending along the sides of the cliffs and slopes or wrapping about the rounded surfaces. Occasionally they curve upwards or downwards, the deepest portion of the groove being along the inner edge of the convex border. In a few cases, they were noticed where the glacier had overridden some of the spurs which project into the fiord. Where not associated with these spurs, the billow-like movement of the ice which formed these gouges may have been caused by inequalities of its bed; by variations in width of the valley, which caused congestion and rising in the narrows, and spread with consequent descent in the broader cross sections; possibly by the influx from some tributary glacier which would cause resultant readjustments within the plastic mass. The interiors of many of the grooves are polished or finely striated, and the writer has come to the conclusion that some of these furrows were formed not by a single gouging or plough-like action, but by persistently dirty streaks within the ice, whose abrasive action may have been as gradual as that which caused polishing upon other surfaces. A single boulder may have formed an initial groove which has been greatly deepened by finer material.

In several places where the slopes were steep with a more or less rounded surface, peculiar "lunoid furrows" or "crescentic gouges" occur, which are similar to those described by De Laski,[1] Packard,[2] Chamberlain,[3] Daly[4] and Gilbert.[5] They were numerous and well-developed on the left side of the entrance of Bond sound. These crescent shaped depressions are

[1]Amer. Jour. Sci., 1864, Vol. XXXVIII, p. 337.

[2]The Labrador Coast, p. 298. (New York and London, 1891.)

[3]U.S. Geol. Surv., 7th Ann. Report, 1885-86, pp. 218-223.

[4]Bull. Harvard Museum of Comparative Zoology, 1902, Vol. XXXVIII, pp. 237-245.

[5]Crescentic Gouges on Glaciated Surfaces, by G. K. Gilbert, 26 pp. (Roch, 1906.)

abrupt on the concave side, which is turned toward the direction from which the ice came. The steep concave edge is rough in some of the lunes and smooth in others. The distance between their horns varies from three inches to a foot in width, and a few have a maximum depth of about two inches at that point through which their axis of symmetry passes. Sometimes only single lunes have developed, but frequently they are arranged in a series, with a common axis, which is coincident with the direction of the striae. It would seem that these peculiar tracks are undoubtedly the result of glacial action, which, however, was assisted in their formation by a tendency of the granite to exfoliate. The ice in dragging a boulder across the edges of these dormant and invisible plates would exert shearing stresses, that would cause the outer portions of these layers to scale off with an inner lunoid fracture.

(2) *Roche Moutonnees.* This glacial form is especially characteristic of the surface of many of the smaller islands. They appear as long swells or elongated hummocks, which are parallel and trend in the directions assumed by the ice-flood. They have a broadly convex longitudinal outline, or a gentle slope on their stoss side, and a steep and rough face on the lee side. Not only do they occur upon horizontal surfaces but upon slopes and occasionally they have been carved upon steep cliffs. When in the last position, they seem to be flatter and broader. A few of the mountain summits which were covered by the ice have the flowing outline of the roche moutonnée type. Snow mountain, 3000 feet in altitude, as seen from a point near Indian island in Havannah channel, presents such an appearance.

(3) *Domed Surfaces.* Many of the granite mountains have the form of domes, with which the name "Cone" is frequently associated on the map. A few of them are of a remarkably symmetrical bee-hive shape; others are irregular, but most frequently the dome outline is developed only on the side which faces the fiord, while back from the shore it merges with the general mountain assemblage. Their surfaces are usually quite smooth and firm, but often display a tendency to peel off in curved plates or scales. Some of the scales have dropped off, others adhere closely to the surface.

The cause of this exfoliation is to be sought in external conditions which have produced or permitted expansion, since it is not dependent upon any structure exhibited by the granite. Where forest fires have raged within the district, as along Ramsay arm, they have caused the granite to peel off to a surprising degree, giving emphasis to the well known fact that exfoliation is frequently associated with changes of temperature. Expansion with consequent exfoliation may also be produced by weathering, or, as Gilbert[1] suggests, by the removal of a thick covering under which the granite has cooled, and thus permitting expansion to operate where previously compression was the rule.

The reason that these domes are discussed in this relationship lies in the fact that some of them have been scarred and rendered asymmetrical by ice erosion. The face nearest the ice stream has been cut across irrespective of exfoliation. An example of such a scarred dome may be seen at the head of Call creek (see Plate VI (a)). In very many cases, however, the ice has moved around them, stripping them of all scales, scoring and striating their surfaces in a horizontal direction, and yet preserving the symmetry of form. The occurrence of domes along the sides of the fiords should be an important feature in the discussion of increase in valley width through glacial erosion. That such an alteration has taken place can hardly be doubted after a study of other characteristics of the topography. It may be suggested that the secular variations in climate, which, during the Glacial Period, attended the oscillations between inter-glacial and glacial conditions, may have accelerated the process of exfoliation. The ice in an advance removed the scales and plates, and, finding the rounded surface well adjusted to its movement, proceeded to scour it in a fairly uniform manner.

(4) *U Shaped Valleys.* All of the fiords and larger land valleys within this district have the habitual U shaped cross section of a glacially eroded valley.

[1] "Domes and Dome Structure of the High Sierra," by G. K. Gilbert. Bull. Geol. Soc. of Am., Vol. XV, 1903, pp. 28-34.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

1.0 2.8 2.5
3.2 2.2
2.0
1.1
1.8
1.25 1.4 1.6

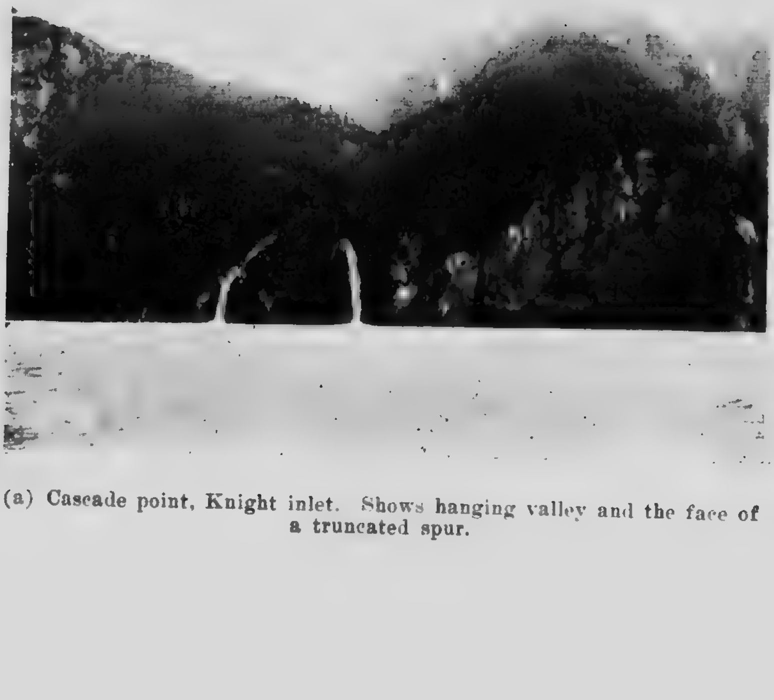
A water stream erodes a V shaped valley, in which the angle of declivity of the lateral slopes depends, in general, upon the amount of elevation of the land, and the stage which the river has reached in the development of its life history. A mature river is one which has been at work for a sufficient length of time to cause the rapids, waterfalls and lakes to retire toward its headwaters. In a mountainous country, its valley, which was canyon-like when young, has been widened in contrast with its depth, and the river sweeps in serpentine curves upon its flood plain. The view, either up or down stream, is limited by the presence of overlapping spurs, which alternate upon either side of the valley in positions dependent upon the winding character of the river.

From the description already given of the mainland fiords and of the rivers which enter at their heads, it is evident that they present many of the characteristics of mature rivers in common with others which emphatically distinguish them from this type. The U shaped valley, the truncation and alignment of spurs, hanging valleys, through valleys and the present configuration of the floor of the fiords are not features that are associated with the development of the mature type of stream valley.

When young, a river may flow in the bottom of a deep canyon, occupying all of the floor space between the walls; during its later stages, it follows a *channel* which threads its way along an established flood plain. A glacier, on the other hand, occupies the whole *valley*, filling it with ice to a depth commensurate with the amount of precipitation and the prolonged frigidity of the climate. The viscous nature of a glacier does not permit it to readily adapt itself to a valley which has been eroded by the more agile movements of a river. The glacier proceeds to adjust the stream valley to a form more suited to its own cumbersome advance. Valley glaciers must widen former stream valleys very considerably, in order to produce the initial change in the shape of a cross section from that of a V to that of a U. Within this region they have not only made this change, but they have given width and depth to the U when once established.

(5) *The Truncation and Alignment of Spurs.* In widening a stream valley, a glacier truncates and otherwise alters the overlapping spurs.

Plate V.



(a) Cascade point, Knight inlet. Shows hanging valley and the face of a truncated spur.

PLATE V.

(b) Cascade point, Knight inlet. Shows profile of the truncated spur.

Some of the spurs within these fiords have been shorn off completely; many others have been so worn back that to-day they present very steep lower slopes, and occasionally terminate in cliffs which are often several hundred feet high. This action on the part of the glaciers has given rise to long "reaches" along which the spurs are in almost perfect alignment. Knight inlet, from its mouth almost to Glendale cove, presents such a reach, which is 33 miles in length. The channels between the islands have had their spurs so closely shorn that for long distances the view is not obstructed by a single prominent spur. The bluntness of the ends of the islands on the east side of Johnstone strait is a striking feature in this relationship.

On the other hand, a good many overlapping spurs still remain, but the modifications in form which they have suffered make plain the methods used by the ice-flood in its attack. While the greater thickness of ice in the central portion of the valley was wearing back their faces, the lesser thickness of ice which passed over them profoundly altered their original shape, and, in several instances, imparted a remarkable concavity of outline to them. The spurs on the right hand side of the Klena-Klene river are worn down to an almost common level. (Plate VI.) Occasionally the ice from lower depths seems to have arisen and passed over their outer ends, for the striae were noticed to curve obliquely upwards on the upstream side of a few spurs. Naturally glaciation was most intense on this stoss side of the spurs, which in many cases proved to be such effective barriers that the ice literally flowed around them, as is evidenced by the steepened, rounded and horizontally scored surfaces. This is especially true where the fiords have a winding course, as toward the head of Knight inlet The glaciers have accentuated the receding embayments which in mature river valleys alternate with the spurs, and in doing so have rendered more prominent the base of spurs themselves.

The step-like outline, which characterizes a few spurs, has been produced by glacial plucking, where the ice has removed large blocks whose size and shape were previously determined by the jointed structure of the granite. It was this process of plucking, combined with what seems to be the

more important, slow but sure grinding action of the ice, which has caused so many of the spurs to recede, and which has otherwise altered the form of these valleys.

Fig. 7. Looking up Bute inlet from Fawn bluffs. Shows the step-like outline of some of the spurs.

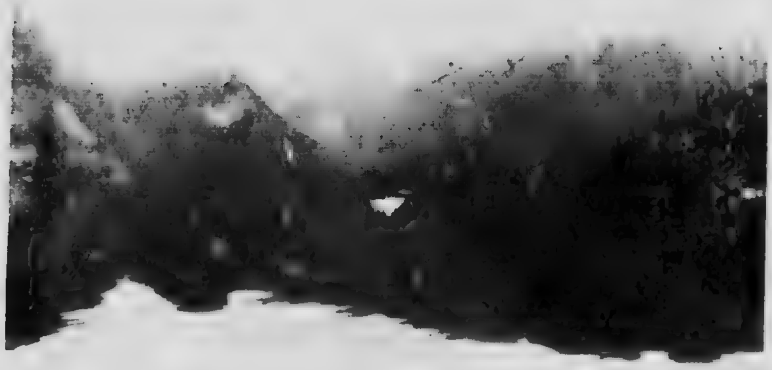
(6) *Cirques.* These amphitheatre-shaped hollows, which have been sculptured by individual glaciers, are most numerous among the higher altitudes, but in a few instances they descend to within a few hundred feet of sea-level. Many of the higher summit cirques are still occupied by patches of ice or by glaciers, which seem to cling like limpets to the steep walls or are situated in hollows between the peaks.

In the excavation of cirques, the ice not only deepens the floor by its erosive power, but with a sapping action, which is not as yet thoroughly understood, it causes a recession of the rocky walls. This recession is supposed to be produced chiefly by the repeated freezing and thawing of the upper and steeper part of the wall ("bergschrund"), along the line of the crevasse which develops at the head of the glacier.[1] The debris, which is thus pryed off by the action of frost and glacial plucking, is removed by the glacier, which uses this material to scour the floor of the cirque.

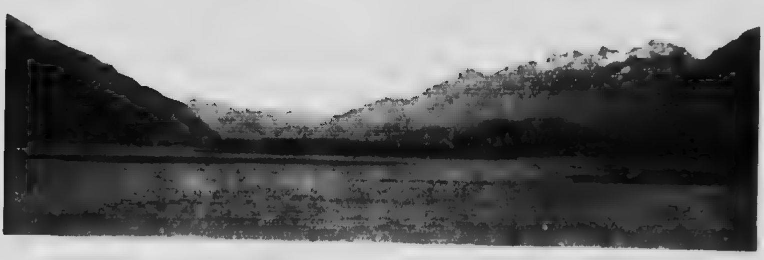
Some of the serrated and scalloped mountain crests, which impart variety to the widespread rounded summits, owe their irregularity of outline to the development of a series of small cirques which are almost adjacent to one another. Examples of such crest lines are especially numerous toward the heads of Bute and Knight inlets. Many of these summit cirques are situated above the limit of general glaciation. Not only have they been hollowed out by modern glaciers, but in the incipient stages of their development they were probably

[1]See "The Profile of Maturity in Glacial Alpine Erosion," by W. D. Johnson. Jour. of Geol., Vol. XII, 1904, pp. 569-578.

PLATE VI.



(a) Head of [illegible]



(b) Head of Knight inlet, looking up the valley of the Klena-Klene river.

occupied by ice during inter-Glacial epochs, and for a time immmediately preceding the Glacial period. The descent of the neve line, which accompanied the formation of confluent ice sheets, may have produced pauses in the history of their erosion by ice.

Some of the summit cirques upon the lower mountains seem to have been formed since the period of maxium ice-flood. For example, the cirques shown in Plate VII (a) are situated at an altitude of a little less than 3000 feet. Numerous large cirques are situated below the level of Pleistocene elevation. The largest of these old glacial reservoirs, which was seen within this area, occurs just beyond Cascade point in Knight inlet (Plate VII (b)). Located in a corner which is shielded from the sun, its situation is an ideal one for the accumulation of ice. The fresh appearance of its splintery sky line, its steep, rocky walls, the low-lying, sheltered patches of snow and ice, and the bow-shaped outline of the terminal moraine impress the observer with the rapidity in the near past of vanishing glaciation.

(7) *Through Valleys.* Not only did the ice-flood impart smooth and graceful outlines to the summits over which it passed, but it carved out U shaped passages across the divides. It does not seem possible to offer any other satisfactory explanation for the sky lines presented by certain ridges within this district. An elongated mountainous obstruction, situated in a position transverse or slightly oblique to the general direction of ice movement, would afford the most favourable conditions for the formation of this glacial feature, since it would be analogous to a dam across a river. Where pre-glacially eroded notches or passages existed in such a barrier, there the largest volume of ice would flow across during the period of maximum flood. Even if the ridge were then covered, the rising or subsiding ice-flood would continue to move through the passes for a longer time than across the crest. Such preglacial passes would thus be altered to the form of U shaped *through valleys.*

A beautiful example of a valley of this type may be seen inland from the head of Topaze harbour (Plate VIII (a)). A similar valley of even more remarkable diagrammatic outline extends across the peninsula between Boughey bay and John-

stone strait (Plate VIII (b)). On either side of the valley, which pierces the peninsula at a point where it is only one mile and a quarter in width, the mountains rise quite abruptly to altitudes of about 1500 feet. Some of the ice from Havannah

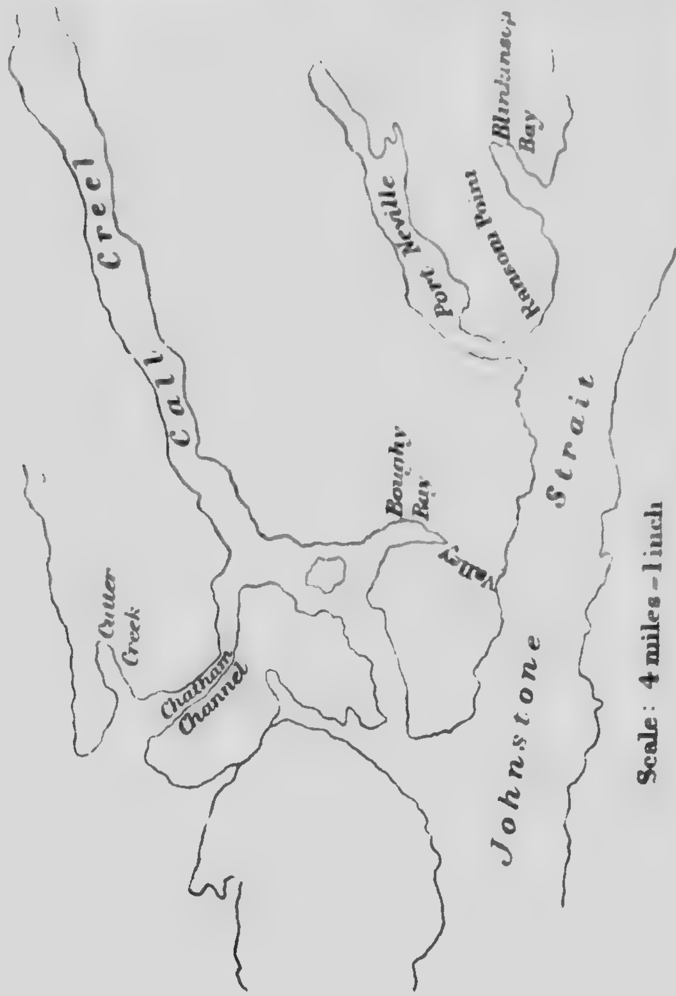
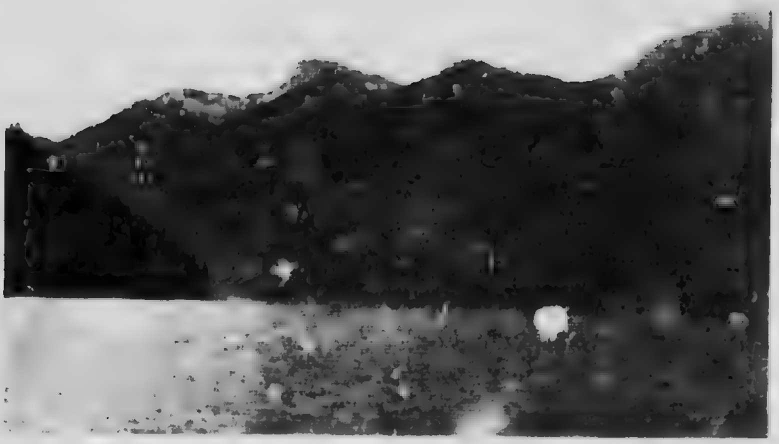
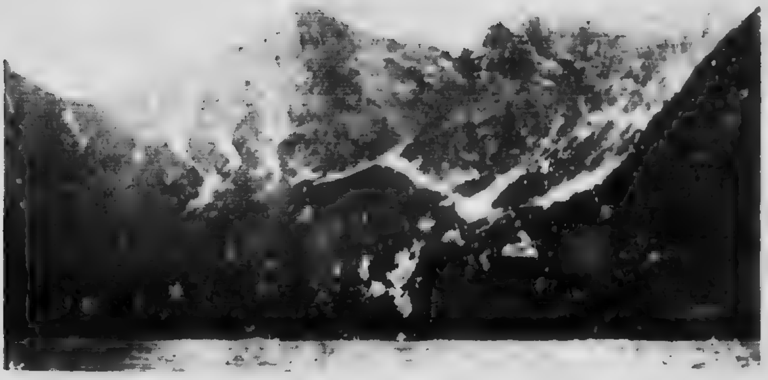



Fig. 3. Shows position of through valley extending from Boughey bay to Johnstone strait.

channel sawed its way across a pass in a divide which formerly separated Boughey bay and Johnstone. Other less



(a) Small cirques near the head of Loughborough inlet.



(b) A large cirque near Cascade point, Knight inlet.

Plate VIII.

(a) Through valley, head of Topaze harbour.

(b) Through valley, looking west from the head of Boughy bay.

striking examples of this topographic type were noticed in the district.

These *through* valleys bear emphatic testimony in favour of most vigorous ice erosion, or, rather, of the great length of time during which the ice was flowing across certain divides. Tarr,[1] who first described them under this name, tells us that:—"In some places in Alaska, the ice is still pouring across the divides." Penck has recorded their presence in the Alps, and Davis,[2] under the heading of "Glacial Overflows," has described the same topographic features from the Snowdon district in Wales.

(8) *Hanging Valleys.* Several good examples of this prominent glacial feature occur within this region, one of which is displayed in Plate V (a). Where they open along the sides of the fiords, their floors are estimated to be from one or two to twelve hundred feet above sea-level. This discordance in level between the tributary and main valleys constitutes their most striking characteristic; but in addition to this, they possess the same U shaped cross section and truncated spurs as the fiords themselves.

More than any other single physiographic feature, hanging valleys of this type have convinced many students of the potency and vigour of glacial erosion during Pleistocene time. It is recognized that, although under exceptional circumstances the tributaries of a river may assume a hanging position, such lateral valleys are very different from those which are met with so frequently in glaciated mountainous districts. In the very earliest stages of stream development, the trunk may entrench itself more quickly than its tributaries, but such hanging valleys are not a normal feature of a mature river system. During the stage of maturity, they can only be developed by a variety of possible accidents. For example, faulting may cause the main valley to drop down in the form of a graben, leaving the tributaries suspended along the face of the fault scarp; or, by rejuvenation through uplift, the parent stream, because it follows a rock formation or structure which is more easily eroded than that along which the lateral streams flow, may entrench itself more rapidly than

[1]Pop. Sci. Monthly, Vol. LXX, 1907, pp. 99-119.

[2]Quart. Journ. Geol. Soc., Vol. LXV, 1909, p. 341.

its tributaries; or, while crossing an arid region, a river may receive tributaries which are so spasmodic in their flow that they are unable to establish an accordant junction with the main stream.

Other events, which are equally exceptional in the life history of a normal river system, may form hanging valleys; but their occurrence within this region apparently cannot be explained from comparison with these abnormal products. Hence the suggestion, that they are modified hanging valleys which were eroded by pre-glacial streams, seems to be eliminated.

It is believed that they are the result of differential ice erosion; that the discordance in level expresses approximately the difference between the erosive power of the volume and thickness of ice which occupied the main valley and that which filled the tributary. The mathematical accuracy of this implied proportion is modified, however, by the widening of the main valley, through which process not only the spurs were truncated, but the lower courses of some of the tributaries were shorn off. Moreover, some of the lateral valleys must have been occupied by ice for a considerable time after the ice had disappeared from the fiords. As the soundings on the charts show, a widespread and uniform elevation of this district would convert many of the lateral bays and smaller fiords into hanging valleys.[1]

(9) *Heads of the Fiords.* At the head of some of the smaller fiords, the deltas are as yet in the initial stages of their development, and an opportunity is thus afforded to examine bed-rock conditions. Some of the fiords have a width at their head which, if their origin be attributed to stream erosion, is not in accord with the narrower valleys which extend inland. Wah-ka-na bay on the east side of Gilford island, Kwatsi arm, Call creek and Ramsay arm, on the mainland, may be cited as examples of fiords in which deep water per-

[1]For further information concerning hanging valleys, reference is made to:—

(1) "Glaciers and Glaciation in Alaska," by G. K. Gilbert. Harriman Alaska Expedition, Vol. II, pp. 114-119; pp. 142-150.
(2) "Glacial Erosion in France, Switzerland and Norway," by W. M. Davis, Proc. Bost. Nat. Hist., 1900, Vol. XXIX, pp. ?
(3) "Hanging Valleys," by I. C. Russell. Bull. Geol. Soc. of Am., 1904, Vol. 16, pp. 75-90.

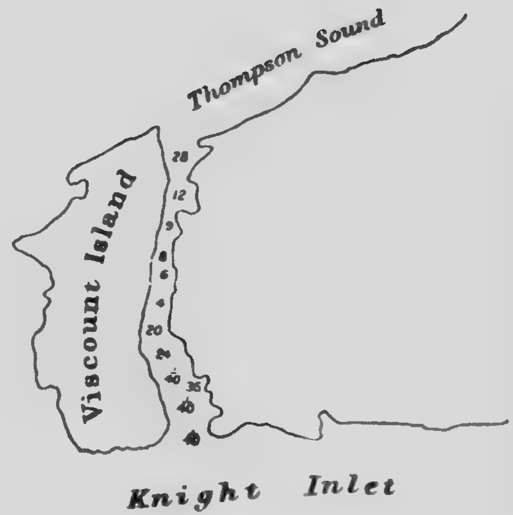
sists from the entrance almost, if not quite, to the head. Except at the mouths of the streams where small deltas are forming, the shore at their heads is bounded by solid rock, which descends quite abruptly into the sea, presenting an appearance of a modified or overridden cirque. It would seem that in some of the fiords there has been a retreat of the head inland, produced by the sapping action of the ice in a manner analogous to that by which cirques have been formed. In those fiords which head in large deltas, similar conditions may prevail, but being masked by these alluvial deposits, the bedrock relations are not so clear. The deltas have been formed since the last advance of the ice, and if it were not for the probability that their rate of accumulation has varied greatly, they would afford a basis for calculating the length of postglacial time. During the glacial period the heads of the fiords were characterized by retrogression; since then they have been the scene of aggradation.

(10) *The Islands.* The maze of islands which fringe the coast are separated by a labyrinth of channels, many of which seem to defy an attempt to relate them to pre-existing stream systems. While some of the channels are fairly uniform in width and depth, others have a definite narrows, where the water is shallower and away from which, in either direction, the breadth and depth of the water increases. This latter condition implies the submergence of a divide. In some of these narrows, the water is so shallow that they are only navigable during high tide; in others, the divide is then barely covered; and a further stage produces ragged peninsular conditions. These gradations are well depicted in the accompanying maps.

Some of these islands have been formed by the simultaneous deepening of the strike and transverse valleys through the scouring and excavating action of the ice; but a larger number seem to owe their origin to the dissection of the interfiord belts through the headward recession of their branches. What were once lateral bays, situated more or less opposite to one another on adjacent fiords, receded headwards until their waters united. When the divide between two such branches had been sufficiently lowered, the ice would pass over it during the higher stages of flood, creating a through valley, the floor of which may have been eroded to a depth more or less in harmony with that which prevailed at the


Scale: 2 miles - 1 inch

Fig. 3.




Scale: 2 miles - 1 inch

Fig. 4.

These figures illustrate the manner in which some of the islands may have been formed.

mouths of the branches. It seems probable that if a sufficient length of time be granted, a channel of uniform depth and width might thus be established.

Except in their seaward extensions across those fiords which are parallel with the Coast Range, the number of islands within the transverse fiords is small. The occurrence of islands within fiords has occasionally been cited as a feature which is inconsistent with a glacial origin. It would seem, rather, that their presence should be expected. While widening their valleys, the glaciers would not only encounter the differential resistance to erosion of rock structures and composition, but also pre-glacial irregularities in topography. Some of the islands are situated opposite retreating spurs, and doubtless represent the position which the spur ends once occupied. Above sea-level, a few spurs may be seen, which are so concave in profile that their outer portion is considerably higher than the inner. (See Plate VI (b).) A certain amount of submergence would convert the outer part of such a spur into an islet.

Islands situated within a fiord may be regarded as a transient feature in its development. It seems impossible to conjecture how much their altitude has been lowered by that agent which blazed its trail with the striations and deep grooves which to-day appear so fresh upon many of their surfaces.

The sandy islands, Harwood, Savary, Hernando and Mary, together with the similar areas on the southern extre[illegible] Cortez and South Valdez, probably represent portions of a glacial apron which was deposited in front of the Gulf of Georgia glacier during a period of hesitation in its retreat. The most exposed portions of their sandy shores are being rapidly worn away by wave action and tidal currents. The position and form of their sand spits are, likewise, a direct resultant of the directions assumed by the prevailing winds and tides.

### Conclusions.

In accord with the evidences presented, the writer believes that the fiords represent pre-Glacial valleys which have been *very much* modified by the processes of glacial erosion which

were active during a long period of time. During the Pleistocene period, glaciers descended from snow-fields on the western slopes of the Coast Range, filling these valleys, at the time of maximum glaciation, to a depth of at least between four and five thousand feet. Through certain gaps in the Coast Range, such as those afforded by the valleys of the Homalko and the Klena-Klene rivers, a certain amount of glacial ice may have emerged from the "Cordilleran ice sheet" which occupied the interior plateaus. Passing westward, these valley glaciers of the mainland became confluent on those forelands whose altitudes were below the upward limit of glaciation, and among the off-shore islands where the glacial mass also received tributaries from the mountainous interior of Vancouver island.

The data collected concerning the directions toward which the ice moved corroborates the views which were advanced by the late Dr. G. M. Dawson. Between Vancouver island and the mainland, the ice flowed both to the northwest through Queen Charlotte sound and to the southeast through the Gulf of Georgia. While the major portion of the large tributary glacier, which emerged from Bute inlet, passed to the Gulf of Georgia, a part of its ice seems to have discharged through Cardero channel toward Queen Charlotte sound. From a location near Plumper bay in Discovery passage, the ice moved in these opposed directions.

In its movement the ice was controlled largely by the sinuosities of the valleys through which it passed. Within those fiords where the mountains on either side rise above the upward limit of glaciation, this control of the ice movement was absolute; but, as is to be expected, where the ice spread out upon the lower forelands and islands, it moved in different directions at different levels within the ice-sheet. The lowest portion of the sheet followed the channels, at a less depth the ice passed across the obstacles in its path, but, in doing so, was influenced by the irregularities of their topography. For example, the ice not only passed through the channels about Hanson island, but it apparently moved across the island in a general northwest direction.

The evidences of the potency of glacial erosion in this district, as described in the preceding pages, are so convincing

that the author is led to the conclusion that by its processes the valleys were not only widened, but their depth was increased by at least from one to two thousand feet. This increased depth permitted the sea to occupy the valleys upon the recession of the ice. Some subsidence may also have taken place, but of this there seems to be no proof within this region. On the other hand, the existence of terraces of sand and gravel, and of stratified clays bearing marine shells, affords direct evidence that post-glacial uplift has taken place.

## FLORA[1] AND FAUNA.

The coast of British Columbia is remarkable for the density of its forest growth and the large size of its individual trees; but the distribution of this timber wealth is far from uniform. Along the mountainous shores of the fiords and channels the greater proportion of the trees are small and of inferior quality. This is due to the lack of soil covering and exposure to the prevailing winds. In some places, barren and polished walls of granite are almost as destitute of vegetation as the day, thousands of years ago, when they were uncovered by the retreat of the glacial ice sheet. Granite mountain on Bute inlet, which rises from sea-level to an altitude of 6,653 feet, is a most impressive example of the manner in which such rocky slopes have resisted the advance of vegetation. There are no less than four Bare mountains within this area, and one named Mt. Baresides. From this extreme there is every gradation to the vigorous growth which clothes the slopes of easier inclination, and the dense, majestic forests of the valleys and more level interior areas which are sheltered from the violence of the wind. In many places, the forests clothe the slopes with such an impenetrable covering that the geologist has little opportunity of interpreting the rock structures which are so effectually covered.

The Douglas fir (Pseudotsuga Douglasii), which is in great demand on account of its length, straightness and strength, is abundant in the southern and eastern parts of this district. North of a line extending from the entrance of Call creek westward through Harbledown island, only a few representatives of this tree were seen.

[1]For more general information, see Note on the Distribution of some of the more Important Trees in British Columbia, by G. M. Dawson. The Canadian Naturalist, Vol. IX, No. 6.

Other coniferous species, which in greater or less abundance contribute marketable timber throughout the whole of this region, are included in the following list:—Western cedar (Thuja gigantea), hemlock (Tsuga mertensiana), Menzies spruce (Picea sitchensis), yellow cypress (Thuja excelsa), and the white pine (Pinus monticola). Scrub pine (Pinus contorta) grows in a scattered manner upon th[illegible] and more rocky slopes. Hemlock, cedar and spruce at[illegible] magnificent size, and, north of the line previously me[illegible] constitute by far the most important timber producers[illegible]all creek a cedar, which had been recently felled, was [illegible] throughout and had a diameter of twelve feet at the ba[illegible] The yellow cypress is usually found in the higher altitud[illegible]t on Queen Charlotte sound descends to tide level in a f[illegible] places, [illegible] Sargeaunt passage just back of the cannery [illegible]

With the exception of the yew (Taxus brevifolia) [illegible] (Alnus rubra), deciduous trees are not common. South of a line from about Chatham Point on Vancouver I[illegible] ward to the entrance of Toba Inlet, a few shrubby forms of the evergreen arbutus (Arbutus Menziesii) occur. The alder in this district is a small tree which is often twelv[illegible] inches in diameter. Near the coast the broad lea[illegible] maple (Acer macrophyllum) is sparingly fou[illegible] a few ind[illegible] of this species being noticed as far north as the hea[illegible] of Bute inlet.

The dense nature of the forests along this coast [illegible] due largely to a luxuriant thicket-like undergrowth whi[illegible] ter- spersed with fallen trees. Especially is this true [illegible]able localities along the actual shore line to an altitude of 2000 feet, and in all valleys and ravines. Often a pedestrian may traverse a considerable distance by choosing a path along the larger trunks of fallen trees, which frequently bridge the hollows and thus raise him above the tangle of brush and fern. The alder, elder, dogwood, willows, crab apple, salmon berry, blackberry, raspberry, ferns and the prickly devil's club are the common[1] members of this undergrowth family.

In the interior of the islands, the forests are often less impenetrable, and one may walk along upon a thick carpet of

[1]For the names of other shrubs, flowering plants, mosses and lichens from parts of this district, see Ann. Rept. Geol. Surv. of Canada, 1886, Part B, Appendix II, pp. 115-120.

moss among the gigantic trees. In certain inland parts of South Valdes island, there seems to exist good evidence of a great prehistoric forest fire. If the moss and vegetable mould be removed to a depth of a foot or slightly more, a thin layer of wood cinders if often exposed. No ancient charred stumps were noticed standing, while conifers, some of which are hundreds of years old, show no signs of fire upon their bark.

The steep cliffs and lofty trees are a natural habitat for numerous eagles, hawks and crows, whose presence probably explains the almost complete absence of songsters. The large blue grouse, the ruffed grouse and the spruce partridge inhabit the sunny spots where the forest is least dense. Aquatic birds, gulls and several varieties of duck are abundant, large colonies of the former using Mittlenatch island in the Gulf of Georgia and Deep Sea bluffs on Tribune channel as nesting grounds.

Black and cinnamon bears are common upon the mainland, especially along the upper reaches of Knight inlet, from which locality a few grizzlies have also been reported. The lower wooded slopes are often covered with a network of well-trodden trails worn by the Columbian or coast deer, and on the mainland, winding paths of the daring mountain goat extend upward to rougher and higher levels. Deer seemed to be especially abundant on Cortez, Valdes, Thurlow and Gilford islands and in the vicinity of mainland streams. The mountain goat lives on the mainland, being most numerous on Bute and Knight inlets. The big-horned mountain sheep is scarce, though it may still be found among the more elevated peaks. Otter, mink, marten, and beaver, although once plentiful, are now rarely seen.

The more important fish in these waters are salmon (five varieties), red and rock cod, herring, dogfish, and oolachans. The hairy or harbour seal was frequently seen. Whales were numerous, especially in the vicinity of Bute and Toba inlets. A combat which was witnessed between two whales and a swordfish served to reveal the presence of the latter. Along the shore, between the levels of high and low tide, the rocks are widely covered by barnacles, which are frequently so abundant that a uniformity of appearance is imparted to different rock varieties. In the limited areas where sandy

beaches have been formed large clams are plentiful. On the north side of Savary island the largest clam flat is situated. This shell-fish forms an important element in the food of the Indians, the kitchen middies, which are of frequent occurrence, consisting chiefly of their shells. A large variety of starfish of a rich purple hue, a few brilliantly coloured sea-anemones, and numerous crabs are also prominent inhabitants of the littoral zone. In the rivers, streams and lakes, trout are most abundant.

## AGRICULTURE.

The traveller who passes through the maze of waterways in this mountainous district may readily come to the conclusion that it offers no inducements to those who desire to carry on agricultural pursuits. Topographically it is not inviting, but the climate is so favourable that all land which is suitable for cultivation should be worked at some time in the future. Flat lands and gentle slopes covered with soil are of very rare occurrence, yet there are numerous small isolated areas of arable land, which in total acreage and fertility represent a considerable potential wealth of agricultural products.

The lowlands at the mouths of the rivers and streams, composed of modern delta deposits, and the patches of bottom lands along some of the valleys, possess soils which are of great fertility and endurance. The most extensive individual areas of delta are those, already mentioned, at the heads of Toba, Bute and Knight inlets. At the head of Knight inlet, the Klena-Klene river enters with sufficient swiftness to deposit coarse and barren gravel along the channel across its delta. As a rule these flat lands are covered with grass and bracken, which shade into forests along the margin. A large part of such alluvial plains are subject to floods from the sea during the highest tides, and from the rising of the rivers, when the snow is melting upon the mountains during the spring and early summer. Not only might this difficulty be remedied, but possibly considerable areas of what to-day are mud flats at low tide might be reclaimed to form extremely fertile tracts by the construction of a system of dykes. The lateral embayments along the larger fiords head in similar smaller lowlands, which should afford an opportunity for the establishment of several happy homes with gardens.

In Loughborough inlet, the slopes of the enclosing mountains are relatively not so steep, and are locally covered with glacial drift or soil formed by the decay of vegetation. With this exception farming and gardening along the shores of the larger fiords must be restricted to the areas of alluvial origin, which have just been described.

In a few cases, the outer margin of the peninsulas separating the fiords are sufficiently low to afford pasturage, and a few tracts of good land. Portions of the coast in the vicinity of Lund, Malaspina inlet, Theodosia arm, Blinkinsop bay, and Port Neville may be noted as examples.

In the northern part of the Gulf of Georgia, the low-lying islands—Harwood, Savary, Hernando, Mary, and the southern extremities of South Valdes, and Cortez islands have light sandy soils, which are, in some places, mingled with clay. These islands embrace 12,500 acres of low land, some of which is suitable for cultivation and the remainder for grazing purposes. A vigorous forest covers by far the greater part of these areas; but, in contrast with the other rocky and mountainous islands of the district, there are a few open glades which support a dense growth of grasses and small bushes.

Among the islands of strong relief there are many small detached areas of excellent land, some of which, near the shore, are now occupied by thrifty settlers. The entrance of each stream is marked by the presence of a small delta. Occasionally a gentle slope is cloaked with glacial drift; and in a few places the shore is bordered by a low sandy terrace, as in Squirrel cove on Cortez island, and the southwest corner of Hardwicke island. Portions of the interior of several of these islands lie at no great elevation above sea-level. It is impossible to form an estimate of the total amount of such land which will be suitable for the location of several small farms. Across South Valdes island, from Granite bay eastward, there is an irregular belt covered by soil of marine origin, composed of modified glacial drift. It is sandy and light upon the higher levels, loam or clay on the lower, while vegetable mould of varying thickness forms the topsoil. A considerable part of the southern interior of Cortez island will be suitable for pasturage. In the vicinity of Hoskyn inlet on North

Valdes (Maurelle) island, certain parts of Reade, Cracroft, Harbledown and West Thurlow islands may be cited as further examples. With the exception of the delta and bottom lands, the axe will have to precede the plough, and although, owing to the cost of labor, such clearing of land is expensive, the fertility of the soil and the climatic conditions combine to offer an ample reward.

Sheltered as this region is from the excessive rainfall of the west coast of Vancouver island, the possibility of large crops of cereals and vegetables, such as wheat, oats, barley, potatoes, etc., is only limited by the distribution of suitable land areas. All fruits of the temperate zone—apples, pears, peaches, plums, cherries, grapes, berries—will grow luxuriantly. These facts have already been partially demonstrated by a few settlers on Cortez, Reade, and South Valdes islands. Hop raising should be as remunerative as it already is in the valley of the Fraser river. With the increasing demands for agricultural and dairy products of the markets of Vancouver, Victoria, and Nanaimo, it does not seem irrational to predict that agriculture will receive more attention in the future. It must be remembered, however, that the topography is such that lumbering, fishing, and mining will ever be the natural industries of this portion of the Province.

## LUMBERING.

At present lumbering is the most active industry within this area. The certainty of definite monetary returns, dependent almost entirely upon the market prices alone, and the easy methods by which logs may be brought to sea-level and transported have caused the staking and operation of timber limits to absorb attention almost to the exclusion of other possible industrial developments. Timber limits within the primeval forest are reported upon good authority[1] to yield from 20,000 to 500,000 feet per acre, while the average cut in Eastern Canada ranges from 9,000 to 15,000 feet.

Although the term "inexhaustible" has been applied to the timber resources of this coast, it is very evident that its application is not justifiable. The heavy timber growth is confined to limited areas. Even at the present rate of production, many timber claims once regarded as inaccessible and others

[1]British Columbia, its Resources and Possibilities, Victoria, 1893, p. 65.

once considered not worth acquiring have been taken up. In the year 1907, no less than 10,924 square miles were staked as timber limits in British Columbia. On account of the vast areas applied for during that year, the Government has wisely declared a reserve of all timber lands now undisposed of. Even within this area the day is not far distant when the large trees will be a feature of a remarkable past. Smaller trees, which in the Eastern part of this continent would be regarded as valuable, are often cut down and burnt, or left to decay. Forest fires have ravaged wide areas, as in the vicinity of Bute inlet and Ramsay arm, and their smoke creates a heavy haze upon many of the summer days.

If once the forest is cut down, reforesting will be a difficult or impossible problem in many parts of this district, since the removal of the trees permits the scanty soil to be readily washed from the steeper slopes, thus changing portions of this wonderful landscape into a veritable rock desert. The naked rock appears everywhere in those areas where the forest has been destroyed by fire. Although tl.s danger, upon a large scale, is not immediate, except through the lack of individual responsibility wth respect to fires, the Government would do well to reserve one or two of the most picturesque fiords as parks, while they are yet in a state of almost primeval grandeur.

Logging is now carried on near the shore upon the more heavily wooded slopes and at the entrance of many of the valleys. In some cases a large tree may be felled at an altitude of a thousand feet or more; the bark is peeled from it, and, when once started in movement, it frequently plunges directly into the sea. Donkey engines are quite universally used in dragging the logs to a chute which extends to tide water. The depth of water near shore in such cases facilitates the lumbering industry. On South Valdes island a railway about four miles in length has been built, and this represents the farthest distance from the seashore at which operations were in progress during the summer of 1907. After the logs reach the sea they are collected in booms of great size, which are towed to the mills at Vancouver.

## FISHING.

In 1907 a salmon cannery was opened at Sargeaunt passage, near the entrance of Knight inlet, to supply which a small fleet of fishing boats was distributed in the bays of Tribune channel and Knight inlet. The proprietor seemed to be well pleased with his first season's catch of salmon. In Heydon bay, on Loughborough inlet, six Japanese were engaged in fishing and curing salmon and cod. Fishing, as a business, was limited to these ventures; but the inhabitants were frequently seen fishing for their own use. The Indians subsist largely upon salmon, catching sufficient during the summer for winter consumption. In the spring they resort to the head of Bute inlet or Knight inlet, where the oolachans appear in large shoals. This fish, which is about as large as a herring, is their chief source of oil, the smoked and dried bodies afterwards being used for torches as well as for food. Fishing as an industry, and especially deep sea fishing in Queen Charlotte sound and adjacent channels, undoubtedly deserves more systematic attention. Salmon seemed to be very numerous on the northern shores of Gilford island, and especially in Viner sound.

## OTHER INDUSTRIAL POSSIBILITIES.

The readily accessible raw materials, the cheapness of transportation, and the increasing demands of the markets of the Western parts of North America, Asia and Australia should make this coast a good centre for the production of pulp and paper. Much of the waste connected with present lumbering operations might be utilized in the manufacture of these products. The large quantity of scrub pine, which is usually so inferior in quality that it is not suitable for lumber, suggests the successful manufacture of turpentine. Oil of cedar might also be distilled from the leaves and branches of the abundant cedar tree.

The areas of stratified rocks deserve systematic and thorough prospecting. Materials for the manufacture of bricks and lime await demand and necessary capital for development. In several localities suitable stone for building and ornamental purposes, traversed by sufficient joints to facilitate quarrying, lies on the very water's edge.

WATER POWER.

The streams within this district which will contribute to a possible development of a large amount of available water power are too numerous to mention. No attempt has been made to estimate the energy which they represent. Their volume fluctuates greatly, the enclosing slopes of their basins being so steep that they readily respond to the irregularities of precipitation. The most constant in flow originate among mountains which are perpetually snow-clad or from glaciers.

By damming the outlet of Estero basin at the head of Frederick arm, or the outlets of the lake at the head of Marylebone inlet on West Redonda island, considerable water powers may also be made available. When demands of modern commerce warrant the development of these sources of power, numerous factories may arise among these fiords, which enjoy such a delightful climate, and constitute veritable cradles for navigation. These water powers may also be called upon to facilitate the development of the mining industry.

TRANSPORTATION AND COMMUNICATION.

The many trench-like waterways of this region are analogous to a vast system of canals; and they form such a network that no point in the area covered by this report is more than fifteen miles in a straight line from the sea-shore. Sheltered from the swells of the adjoining ocean, they provide an easy means of communication in a region which otherwise would be almost inaccessible. Products of the mine, forest and soil may be taken to market at a small cost upon these natural highways for commerce. Large steamers ply regularly through Seymour narrows and Johnstone strait on their way to Alaska. Smaller steamers from Vancouver run two or three times a week, adjusting their points of call to the variable development of possible industries.

Roads of any great length could only be constructed at such an expense that they would not be practical; but in certain localities, for example, such as across a few of the islands and peninsulas, short roads might be easily built after the land had been cleared. The only wagon road in existence

at present extends from Drew harbour to Gowland harbour on South Valdes island. Upon the same island a railway about four miles in length, has been built eastward from Granite bay to bring logs to tide water. A fairly good trail passes from the head of Bute inlet through the Coast Range to the headwaters of the Chilcotin river, thus furnishing communication with the interior plateau.

Within this region lies the only possible route for establishing a railway connexion between Vancouver island and the mainland. In the direction of N. 20° E. from Seymour narrows, two large islands so nearly occupy the whole passage that it is only necessary to cross three narrow channels which have a total minimum width of less than two miles. The route through the mountains by way of the Yellowhead pass, the headwaters of the Fraser, and the descent along the Homathko river to the head of Bute inlet is reported by several authorities to be thoroughly feasible. In order to construct a line from this point, along the side of Bute inlet to its entrance and thence across the intervening islands and waterways, numerous difficult but not insurmountable engineering problems would be encountered. Almost continuous rock cutting along the steep slopes, several tunnels, and the bridging of the narrow channels through which the tide flows rapidly would make it probably more expensive than any corresponding length of mileage in Canada to-day. If once established the construction on Vancouver island of a line to Nanaimo (which is at present connected with Victoria) and to a true oceanic terminus at Alberni is reported to be a comparatively simple proposition.

## INHABITANTS.

The present distribution of the white population has been largely determined by the development of the logging industry. The largest groups live in logging camps, the labourers in which are so nomadic that they cannot be regarded as settlers. Upon some of the islands, and on the southern side of Loughborough inlet, a few families have taken up their residence in locations favourable for agriculture; they usually supplement the produce of their garden by participating in fishing and logging, or by establishing small shops. Hotels have been erected at Lund, Drew harbour and Bold point on

Valdes island, Burwood bay on Reade island, Shoal bay on East Thurlow island, Port Harvey on Cracroft island, and on Minstrel island.

The Indians belong to the Salish and Kwakiutl-Nootka tribes. They speak many dialects, but the majority understand the Chinook jargon, and a few can converse in English. The environment in which they live forces them to spend much of their time in canoes, and to depend largely upon fish for subsistence. To fashion a canoe they select a large cedar tree, cut off a log corresponding to the size of craft they desire to make, and skillfully scoop it out by using a small adze. The life of these Indians is so closely associated with their canoes that their arms are strong and well developed, while their legs are weak and frequently bowed. Five Indian villages are situated within this area—at Cape Mudge, mouth of Bute inlet, at Mamalilicülla on Village island, at Karlukwees on Turnour island, and near Health bay on Gilford island. The last three villages mentioned are very picturesque. The numerous gaily coloured and fantastically carved totem poles, and the rude but substantially constructed one-storey buildings are the characteristics which attract the attention most closely upon approaching. Upon the totem poles, the heraldic ancestry of the inmates is skilfully depicted, although the carving is rough; some single animal figures prominently upon each pole, representing the crest adopted by the family group. The houses are usually large, some of them being forty feet square. They have a frame of heavy timbers covered with broad cedar planks, which are usually placed in a vertical position. The upright logs in the framework, some of which are carved upon the inner side, are usually smaller than the cross rafters which frequently are four and five feet in diameter. In raising these heavy logs to their position, friends are invited to an entertainment in which feasting and dancing figure prominently. The rafters are at first placed upon a low stage, and at intervals during the dance each friend is given a small, round, hardwood stick; one end of each stick is placed beneath the heavy timber, and by concerted lifting, interspersed by further staging and dancing, it is raised into position. The size of these rafters is a matter of pride to the Indian, and it would seem that one may gather at a glance upon entering one of these houses an idea of the united

strength of those who were present at the raising. Several families live in each house, each family apparently having a definite space allotted. In winter fires burn on the floor, the smoke passing out through a hole in the roof, which is in some cases protected by a shield that may be adjusted to the direction of the prevailing wind, or entirely closed. During the dance, the participants dress up in weird costumes and masks. The Indian who gave the information concerning the erection of their buildings also displayed the mask which he wears during festivities. It was cleverly shaped of wood to represent the head of a horse, and bedecked with brilliant colours; placing the detachable ears in position, he placed it upon his head and pulled a string which caused the mouth to open.[1]

Large numbers of the Indians now desert their villages in the summer to work in the canneries, while a few disperse among the islands and inlets to fish and hunt, in order that the winter may be provided for. Some of their earlier customs, such as the deformation of the head while in infancy, have been abandoned.

## GENERAL GEOLOGY

### General Statement.

The records of igneous activity within this region constitute the dominating feature of its geology. Throughout that portion of geological time extending from early (?) Palæozoic to middle Triassic, vulcanism was intermittent, becoming especially intense during the Triassic period, when it manifested itself by the extravasation of a great thickness of massive andesitic lava flows and volcanic breccias. Then followed the invasion of the composite batholith of the Coast Range, which, in Upper (?) Jurassic time, disrupted and metamorphosed the sedimentary and volcanic rocks. The cycle of igneous action closed with the injection of a vast multitude of dykes which traverse both the plutonic and stratified rocks.

[1]For more extended information concerning the social customs, habits, etc., of these Indians, see Kwakiool People of the Northern Part of Vancouver Island and Adjacent Coasts, by G. M. Dawson, Trans. Roy. Soc., Can., 1887, Section II; British Columbia and Vancouver Island, by Commander R. C. Mayne, 1862, pp. 242-304.

Through the activity of erosive processes, the roof beneath which the plutonic rocks cooled has been almost entirely removed and the batholiths themselves have been denuded to various depths. Consequently by far the greater portion of this area is characterized by the presence of plutonic rocks at the surface. Upon some of the islands between Vancouver island and the mainland, a few patches of the roof remain, in which the stratified rocks, though faulted and otherwise disturbed, are in a horizontal position or have low angles of dip. For the most part, the stratified series occur in isolated areas, each of which comprises what Daly has appropriately called a "roof-pendant." Each roof-pendant represents some portion of the roof which foundered during the intrusion of the deep-seated bodies of magma. Their beds are either vertical or dip steeply to the northeast, the strike, in general, corresponding to the N. W.-S. E. trend of the Coast Range. It seems probable that contemporaneously with the intrusion of the Coast Range batholith the superincumbent rocks were folded, and the synclines, being broken across by the advancing magma, permitted the separation of the limbs to form long, narrow roof-pendants. Owing to the absence of fossils and the high degree of metamorphism to which these rocks have been subjected, it is impossible or difficult to determine the position in the stratigraphic column to which the component strata of a single roof-pendant belongs. In no single area within the district is the complete stratigraphic record displayed, so that the sequence suggested in the following table has been compiled from data collected in widely separated localities.

## GEOLOGICAL TABLE

| Name and Age | Character of Rocks | A Few Typical Localities |
|---|---|---|
| Recent | Alluvial and beach deposits. | Deltas at the heads of the fiords and bays, etc. |
| | **Unconformity** | |
| Pleistocene | Terrace-gravels and sands.<br>5. Stratified gravels and sands.<br>4. Boulder clay.<br>3. Stratified sands, clays and gravels.<br>2 Stratified clays, bearing marine shells. Large boulders.<br>1. Boulder clay | Theodosia Arm, southwest part of Hardwick I. etc. Harwood I., Savary I., Hernando I., Mary I., Reef Point, Cape Mudge. |
| | **Unconformity** | |
| Upper (?) Jurassic Coast Range Intrusives | The intrusive igneous rocks of the Coast Range. | Exposed over greater part of this area. |
| | **Igneous Contacts** | |
| Triassic Parson Bay Group | Dark shales containing fossils, grey impure limestones, fossiliferous, argillites, thin beds of quartzite, sheets of diabase and andesite. | Western part of Harbledown I., Swanson I., Bush I., Hernando I., Twin Is., etc. |
| | **Conformity** | |
| Triassic (?) Valdes Group | Massive flows of andesite, volcanic breccias, tuffs | South Valdes I., Mittlenatch I., West Thurlow I., Helmchen I., Hardwicke I., Cracroft I., Hanson I., Harbledown I. |
| | **Conformity** | |
| Upper Palaeozoic Open Bay Group | Argillites, quartzites, cherty bed, schists, intercalated sheets of diabase. | Open Bay, Valdes I., Blinkensop Bay, Port Neville, Eden Pt., West Thurlow I. |
| | **Conformity** | |
| Marble Bay Formation | Massive beds of limestone. | Open Bay, S. Valdes I. |
| Undifferentiated | Argillites, quartzites, schists, intrusive sheets of diabase.<br>Crystalline limestones in thick beds.<br>Argillites, quartzites, thin limestone layers, cherts.<br>Hornblende and chlorite schists, crystalline limestones, slates, quartzites, intrusive and extrusive volcanics. | A more or less continuous "roof-pendant" exposed:—on southern shore Cardero channel; Owen Pt., Frederick Arm; Fanny Bay, Phillips Arm, etc.<br>Fawn Bluffs, Bute Inlet, head of Toba Inlet. |

From the preceding table it will be noted that the writer found no rocks belonging to the Cretaceous coal-bearing series within the region included by this report. A drift boulder containing several specimens of *Aucella Mosquensis* (?), which determined it to be of Jurassic or Cretaceous age, was given to the writer by Mr. E. W. Wylie, Burdwood bay, Reade island. He had received it from a prospector who picked it up on the slope of a hill near this bay, but failed to find any more than the one specimen. It seems very improbable that there are any areas in this region underlain by rocks of this age; but if they occur, they certainly occupy the low-lying areas, and are concealed by deposits of drift.

## Upper Palæozoic.

### MARBLE BAY FORMATION.

This formation consists of limestones, the beds of which are usually from one to six feet in thickness. The name Marble Bay Formation was used by LeRoy[1] in describing what is undoubtedly the same formation in the adjacent area to the south. Owing to the massive character of its beds, it is believed that it may be recognized in isolated exposures of the stratified rocks as marking a definite horizon in the stratigraphic sequence. Where most extensively developed these limestones are fine-grained, compact and bluish-grey in colour, but in many places under the influence of metamorphic processes they have been altered to marbles or have become coarsely crystalline.

They outcrop along the northern shore of Open bay, on the east side of South Valdes island, where, with an almost vertical dip, they strike N 36° W. From this locality they may be traced westward into the interior of the island, where the dip becomes less and they occupy an area which attains a width of about half a mile. The northern boundary of this narrow belt of limestones is defined by a very irregular contact with intrusive granite; the southern, at least in part, by the passage of the limestone beds beneath the argillites, as displayed in Open bay on the east side of South Valdes island. The presence of numerous faults explains the great

[1] Can. Geol. Surv. Report No. 996, p. 16.

variation in the angle of dip, and the alternation of patches of argillites with those of limestone. On the same island, about three-quarters of a mile to the west of the hotel at Bold point, there is a patch of limestones of undetermined area, which have a low angle of dip and are likewise in contact with the granite. Through the solution and erosion of the limestone by subterranean drainage, several small caves have been formed. Two of these caves were entered through lateral openings; one of them being followed for a distance of about twenty-five yards, when the passage became constricted and blocked by dark red clay, which also covers the floor. What is probably an extension of this passage was entered by descending about eight feet through an opening two feet in width, which had been formed by solution of the limestone along a vertical joint. The floor of this small cavern was strewn with bones which were mixed with clay, seven skulls of deer with horns attached being counted among the debris. The roofs and walls of these caves are free from stalactitic growths but have been worn very smooth, and encrusted, here and there, with small crystals of dogtooth spar. Occasionally the limestone has a variegated or mottled appearance, because of partial recrystallization into white marble.

Upon the mainland, a short distance south of Dinner rock, which is situated about eight miles north of Powell river, there is an exposure of marble, presumably belonging to this formation, which is associated with metamorphosed argillites and greenstones. The marble is 65 feet thick, striking N 25° W. with an almost vertical dip. Slickensided surfaces of cracks, which traverse the stratified series, were formed by faulting that probably took place during the injection of the plutonic rocks. It is reported that this formation occupies a small area which is situated three or four miles east of the head of Theodosia arm.

On the Elsie mineral claim, which is situated on the northern side of West Redonda island, about two miles east of Connis point, at an elevation of 400-700 feet, there is a small area underlain by marble in which a deposit of magnetite occurs. Upon the mainland, almost directly opposite to this locality, it is reported that marble is exposed in the bed of a stream which enters Pryce channel about three-quarters of

a mile west of Elizabeth island. These areas are too small to represent upon the geological map accompanying this report.

Near the entrance of Frederick arm, on its northern shore, blue limestone, more or less altered to marble, which presumably belongs to this formation, outcrops for a distance of one hundred yards (strike N. 45° W., dip 90°). Within Philipps arm the same limestone appears on the west side of Fanny bay (strike N. 40° W., dip nearly 90°), and about one quarter of a mile up the second stream which enters this arm beyond Richard point (strike N. 48° W., dip 90°). In Loughborough inlet it outcrops on the southern shore about one mile beyond Campbell point (strike N.22° W.,dip 60° E.). These occurrences of this formation are distributed along a line which probably delineates the trend of a narrow band of limestones and argillites, which is irregular in width, and here and there may be expected to be broken across by the intrusive plutonic rocks. The southward extension of this line intersects the area of sedimentary rocks which occupies the northern corner of Maurelle island. These limestones outcrop along the southern shore of Cardero channel, a short distance southeast of Hall point. It seems highly probable that they represent a portion of the Marble Bay formation, and, if such be the case, it is necessary to recognize the presence of an older series of stratified rocks, upon which the limestones rest comfortably, and which are very similar in character to those which directly overlie them.

Bute and Knight inlets, which penetrate farthest into the Coast Range, cut across several "roof-pendants" which include beds of marble among their strata; but it is difficult to determine from these metamorphosed and fragmentary occurrences of the stratified series whether the marble belongs to this formation or not. For example, in Knights inlet marble is exposed on the eastern shore of McDonald bay (strike N. 45° W., dip 65°-90°); near the mouth of the Matsi valley two beds of marble, one three feet and the other about two hundred feet thick, are interstratified with schistose argillites (strike N. 53° W., dip 76° E.); on Adeane point, a marble occurs which displays a gneissoid appearance upon weathered surfaces (strike N.50° W.,dip variable); on the inner side of Toil point, marble, penetrated by apophyses of granite, strikes N. 70° W., with a steep dip

toward the east; and about a mile beyond Axe point, two beds of marble with a total thickness of thirty feet are exposed upon the northern shore.

Limestones, apparently belonging to the same stratigraphic horizon, are known from many other localities on the coast of British Columbia. Within the region covered by this report, no fossils were found in this formation. At Marble bay, on Texada island, where the formation is typically developed, the writer collected some obscure corals from a bed of crystalline limestone, which outcrops a few feet away from the front of the house occupied by Mr. A. Grant, the manager of the Marble Bay mine. They are silicified, and standing out in relief upon a weathered surface of the limestone they resemble closely the stalks of crinoids, but upon careful observation they are found to bifurcate. These corals were submitted to Professor J. Felix of the University of Leipzig, who determined them to be either *Lithostrotion* or *Syringopora*. Their presence indicates that the Marble Bay formation was not deposited later than the Carboniferous period, the Lithostrotion having lived in the seas of the Carboniferous, while the Syringopora enjoyed a longer life history, extending from the Upper Silurian to the close of the Carboniferous. At Mount Mark,[1] in the centre of Vancouver island, between Qualicum and Alberni, and upon the Baliinac islands,[2] between Nanaimo and Comox, the late Mr. J. Richardson collected fossils from limestones, apparently belonging to the same horizon, which were considered by Mr. E. Billings to be "either Carboniferous or Permian, and probably the former."

## Open Bay Group[3]

### Triassic (?)

#### THE VALDES GROUP.

Under this heading is described a series of volcanic rocks which, with a few intercalated beds of limestone, play an important part in the geology of many of the islands included by this report. In the northern waters of the Gulf of Georgia, Mittlenatch island is composed of these rocks, and on that portion of South Valdes island which lies between lines extending across from Kelly point and Quathiasca cove to the

[1]Report of Progress, Geol. Surv. Can., 1872-73, p. 54.
[2]Report of Progress, Geol. Surv. Can., 1873-74, p. 98.
[3]For description of Open Bay group, see addendum.

southern shores of Open bay and Drew harbour, respectively, they are typically developed. South of the latter line, they pass beneath, and probably underlie the stratified sands and clays of which the southern extremity of this island is formed. Along the shores of Johnstone strait, they occupy the southwestern portions of West Thurlow and Hardwick islands, the whole of Helmchen island, and a narrow area on the mainland extending northward from Blinkinsop bay for a distance of about seven miles. In the southern part of Queen Charlotte sound they appear upon many islands, of which Hanson, Cracroft, and Harbledown are the largest. The considerable part of the shore-line of Vancouver island northward from Seymour narrows, as well as an extensive area upon the northern end of this island, are characterized by the presence of this formation.

Volcanic rocks comprise by far the greater part of the formation, the intercalated sediments being present in only a few localities. In Hyacinth bay, on the west side of South Valdes island, a few massive layers of blue crystalline limestone are interbedded with the volcanics. On the eastern shore of Hanson island, a short distance south from Burnt point, a similar limestone, occupying an area of only a few square yards and abutting directly against the volcanics, seems to owe its position to faulting. In the small area on the mainland, mentioned in the last paragraph, some layers of argillite alternate with layers of volcanic rock. In the former locality they occur near the base, and in the latter near the top of this formation.

Thick flows of basalt and andesite comprise the major portion of the volcanic series, although, locally, agglomerates and tuffs are interbedded with them. These rocks have suffered so much alteration and their beds are so massive that it is difficult to decipher the position of the planes of stratification. When viewed from a short distance off shore, the exposed cliffs occasionally show traces of bedding, which, upon closer investigation, become less pronounced in character. Their angle of dip is generally less than 15°, and was not noticed to exceed 40°. The presence of slickensided surfaces, the local development of narrow schistose bands with a strike corresponding to that of such surfaces, and the repe

tition of beds possessing similar petrographical peculiarities, demonstrate that the formation is traversed by faults. Within the individual areas underlain by these rocks, the throw of these faults is usually small, probably seldom exceeding one hundred feet.

The name "greenstones," which was given to these rocks in the field, proved to be a singularly appropriate one for distinguishing them from other rock formations in this district. Most of them are dark greyish-green in colour, although greenish-black and purple tints are locally present. Their weathered surfaces are usually rounded and hummocky, often having an appearance as if roughly varnished. Locally, as on Hanson island, they have preserved glacial scratches and furrows with a remarkable degree of freshness, but the smooth surfaces are frequently due to induration caused by weathering. In some places their surface is deeply pitted, owing to the differential etching action of the weather upon amygdaloidal beds. Occasionally this action has progressed so far that the surface assumes a slaggy appearance, which somewhat resembles that of a modern lava flow. Upon the northern shore of Hyacinth bay, on S. Valdes island, the pillow "structure" is beautifully developed in one of the flows.

In general, these rocks are compact and fine-grained to cryptocrystalline in texture; but over wide areas they are highly amygdaloidal, the amygdules sometimes comprising one-third of the rock. The numerous amygdules betray the former vesicular character of the rock, and imply that some of the lava flows contained a large amount of gas and vapour, which became imprisoned upon the crystallization of the rock. Occasionally they are elongated in parallel planes, thus exhibiting an excellent flow structure. The vesicles are now filled with secondary minerals, such as quartz, chalcedony, epidote, chlorite, calcite, and zeolites. Chalcocite, chalcopyrite, bornite, native copper, and azurite also occur within the amygdules in many widely separated localities, as on South Valdes island, the southeastern part of Hanson island, on Helmchen island, and in several places along Baronet passage. Of the zeolite family, prehnite and natrolite were the only members which were observed to be present. The former

mineral fills many of the vesicles in a sheet which outcrops at Copper Cliff, and was also noticed in association with natrolite at the head of the southern arm of Hyacinth bay.

Within a given bed, the minerals which occur in the amygdules, or the method of their arrangement, are frequently characteristic features. Thus, in a single bed on the southeastern corner of Hanson island, the majority of the amygdules are lined with chlorite, while their centres are occupied by epidote which has crystallized in the form of beautiful rosettes. In another sheet, which is exposed in Growler cove on Cracroft island, they are lined with chalcedony. At the head of Hyacinth bay a single flow, or a portion thereof, is distinguished by the presence of numerous greenish-black spherical bodies, about the size of peas, which are profusely sprinkled through its mass. These may be readily separated from a decomposed surface of the rock, and a few were noticed to be scattered on the ground in the immediate vicinity of this outcrop. They were found to be composed of chlorite with a little epidote, and from their spherical form and beautiful radial structure were at first believed to be spherulitic in character; but upon examination under the microscope, it was observed that the much altered andesite which contains them becomes more fine-grained about their borders, as is frequently the case on the border of vesicles in lavas, and it was concluded that they are likewise of an amygdaloidal character. On the northern shore of Hanson island the subangular vesicles in certain beds are filled with a dark material, which stands out prominently upon weathered surfaces and possesses a peculiar glazed appearance. These amygdules are occasionally as much as an inch across, and their presence imparts a distinctive character to the rock. Their mineral content consists of quartz and chlorite, the latter mineral permeating the quartz in the form of irregular fibrous aggregates.

In certain localities, large cavities, up to several inches in diameter, once existed in these rocks, but they are likewise now occupied by secondary minerals, which, in their colour and manner of occurrence, form a striking contrast to the fine-grained texture and sombre colour of this formation. Some of these cavities, apparently, have been formed by the ex-

pansion of pent-up gases or vapours, while the lava was yet in a viscous state; others mark the presence of irregularities which developed along planes of faulting or stratification. In such cavities as these, an uncommon arrangement of quartz crystals is of frequent occurrence along the shore of South Valdes island, just south of Seymour narrows. Prismatic crystals of milky quartz are grouped in compact radial aggregates, which attain a maximum diameter of about three inches. Within a single cavity they have frequently developed from several centres. A small amount of chalcocite often accompanies this quartz, but its distribution within the cavity is dependent upon the radial character of the latter mineral. Within the amygdules, quartz frequently displays a tendency towards a similar radial growth, which, under the microscope, expresses itself by a progressive undulatory extinction that might easily be mistaken for strain shadows. Aggregates of epidote crystals in quartz, up to three inches in diameter, occupy cavities in the rock exposed along the southeastern shore of Hanson island.

Veins of secondary minerals frequently traverse the rocks of this formation and are occasionally present in sufficient numbers to form a reticulating network, which gives the rock a streaked appearance. Rarely do these veins exceed a small fraction of an inch in width, although, in a few instances, they are several feet wide, containing copper minerals in a gangue of calcite and quartz.

Along the northern shore of Hanson island, on the western end of Hardwick island, and in the small area occupied by these rocks on the mainland to the north and south of Port Neville, agglomerates or breccias are interbedded with the lava flows. They are largely composed of subangular fragments of greenstone, many of which are highly amygdaloidal; but the matrix which surrounds these fragments has been so altered that in the specimen which was examined its tuffaceous character has been almost completely obliterated.

From an examination under the microscope of thin sections of rocks collected from the massive lava flows, it is found that they are pyroxene andesites and basalts which have been very much altered. The majority of them were originally composed of plagioclase and augite with a few crystals of apatite

and disseminated grains of iron ore. In a few specimens, a subordinate amount of hornblende and a few anhedral grains of titanite are also present. Epidote and chlorite are the most widespread and abundant secondary minerals, their presence readily explaining the green colour which is so characteristic of these rocks. Calcite, quartz, chalcedony, zeolites and leucoxene complete the list of the common products of decomposition in these rocks. When present, the leucoxene occurs in the immediate vicinity of grains of iron ore from which it has been derived. The other secondary constituents occupy amygdules, or are distributed irregularly throughout the compact rock, often being gathered together in nests and clusters, which in replacing the primary minerals gives rise to a pseudo-amygdaloidal structure.

The variation of texture in these rocks is such that in some thin sections the component minerals are barely discernible, while in others the ophitic structure is beautifully displayed. This variation in texture is dependent upon the different conditions under which successive flows have cooled, and upon the fact that the central portion of a single flow, while cooling slowly, has become most coarsely crystallized. Phenocrysts of feldspar, either singly or gathered into irregular groups, are of frequent occurrence, while idiomorphic crystals of augite, which are very pale green or colourless in thin section, are occasionally sprinkled through the rock. In three specimens the feldspar was found to be andesine, occurring in lath-like forms which almost invariably display twinning according to the albite law. One of the amygdaloidal rocks from Hanson island possesses a groundmass of small crystals of plagioclase in a partially devitrified glassy base.

A few narrow beds of chlorite and hornblende schists traverse these rocks. Two such bands were noticed in the field—one on Hardwick island and another on the Ajax claim on the north side of Deep Water bay on South Valdes island. Under the influence of crushing movements, recrystallization has taken place, the new minerals ranging themselves in definite planes at right angles to the pressure, thus producing a foliated or schistose structure.

*Contact Metamorphism.* Upon approaching a contact between these volcanic rocks and those of the Coast Range

batholiths, the former become darker in colour and assume a less altered appearance. From a microscopical study of thin sections, it is plain that this change is due to recrystallization. The rock loses its amygdaloidal character, and hornblende replaces the augite. Specimens were collected at different distances from their contact with the granite at Kelly point on South Valdes island. At the contact, the volcanics display a slight tendency toward foliation, and are composed of hornblende, plagioclase, a few grains of iron ore with some chlorite and epidote. The hornblende, which is the dominant mineral, is strongly pleochroic, the compact individuals of this mineral being very irregular in outline. About fifty yards south of the contact, the rock consists of the same minerals, but the hornblende is of a distinct secondary character, since in a fibrous form it penetrates the plagioclase in all directions. The hornblende is paler in colour, and a greater number of grains of iron ore have separated out. About a quarter of a mile from the contact, where the first indication of the presence of stratification appears, the rock contains a little augite which occurs within the crystals of hornblende, and is so uralitized as to lead one to conclude that at least a large proportion of hornblende has been similarly derived from the alteration of augite. Similar rocks, in which amphibolitization of the augite has taken place, were examined from the contact on the northwestern corner of Hardwick island. Professor J. W. Judd, in describing the Tertiary gabbros of Scotland[1] and Ireland, assigns the processes whereby augite is converted into hornblende to the action of atmospheric agents; but a study of the volcanic rocks in this region shows that this change may also be a result of the infusion of heated vapours and waters which attend the invasion of batholiths.

*Correlation.* Undoubtedly this volcanic series is of the same geological age as the porphyrites, agglomerates, etc., of Texada island. It likewise seems probable that they correspond to the volcanic members of the Victoria Series on the southern part of Vancouver island. It is possible that the Valdes formation may belong to the latest Palaeozoic, but in this report it is provisionally placed in the Triassic.

[1]Quart. Jour. Geol. Soc., Vol. XLII, p. 85.

## Triassic.

### PARSON BAY GROUP.

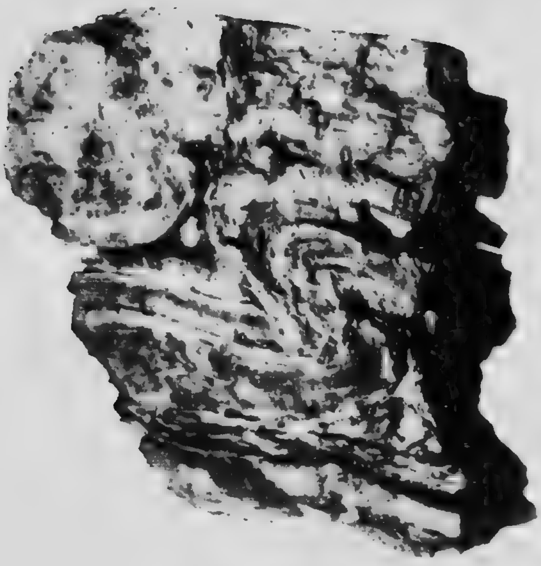
Of more recent age than the Valdes formation are the carbonaceous shales, argillites, impure limestones, calcareous sandstones, and quartzites, which are least metamorphosed and most typically developed upon the western part of Harbledown island in Queen Charlotte sound. For convenience of description, the name Parson Bay Group has been given to these rocks. Interbedded with these sedimentary rocks are a few layers of massive volcanic greenstones which have the composition of andesites. Some of these greenstones are true lava flows, others seem to be of intrusive character, and their presence shows that the volcanic outbursts which produced the Valdes formation gradually became less intense. On a projecting point just to the east of Kelp rocks, on the southern side of Harbledown island, nearly horizontal beds of dark carbonaceous limestone are largely composed of fragments of shells. Among these fragments, those of *Pseudomonotis subcircularis* and *Halobia* were recognized. Diabase dykes of greenish-grey colour intersect the limestones and may be responsible for their impregnation with disseminated grains of pyrite. Parson bay, on the western side of this island, proved to be the most productive locality in the whole area for the collection of fossils. Upon the western shore of this bay, near its entrance, there is an exposure of bluish-grey argillaceous limestones, carbonaceous shales, argillites, and quartzites, which with an almost vertical dip are in contact with intrusive quartz-mica diorite. Upon examination in thin section under the microscope, the limestone proved to be very impure, containing a high percentage of quartz in minute grains, while the presence of microscopical crenulations is beautifully depicted by the arrangement of abundant minute particles of carbon. The surface of some of the laminæ of the shales are covered with the imprints of *Pseudomonotis circularis*, while some of the compact limestone layers yielded beautiful specimens of the same fossil, together with that of a small gasteropod, which, though poorly preserved, is believed to be a *Natica*. On the eastern shore of this bay there is a prominent patch of black carbonaceous shales which are nearly horizontal. From these shales several casts of the ammonite, *Celtites* (?) *Vancouverensis* were collected (see

Plate IX (b). The specimens are mere impressions, in which no trace of a suture line or siphuncle has been preserved. They have not only been almost completely flattened out, but have suffered from lateral compression, with their longer axes corresponding to the general regional strike. One specimen, which shows little more than one-half of a cast, has assumed the shape of an ellipse in which the major axis must have been four inches in length with a minor axis of about two and one-half inches. The late Dr. J. F. Whiteaves has described this fossil as follows:—

"Shell, discoidal, compressed, whorls four to five, slender, "gently convex at the sides increasing very slowly in size "and very slightly involute, so that the whole of the sides of "the inner ones are exposed to view: umbilicus wide and ex-"tremely shallow, outer volution distinctly keeled at the peri-"phery; exterior of the whole test strongly ribbed, the ribs "simple, transverse, generally straight, broadening outwards "and interrupted on the keeled periphery of the outer volution. Siphuncle and septum unknown."

Within this area, the late Dr. G. M. Dawson collected specimens of the same fossil from Hidalgo point on Hernando island in the Gulf of Georgia. In this locality the stratified series, which comprises cherty argillites, quartzites, numerous intercalated sheets of intrusive (?) greenstones, and a layer of blue limestone which is four inches in thickness, are intersected by numerous dark dykes. They occupy a very small area, being intruded by grano-diorite and olivine-gabbro which cuts them off on every side except the northern. On Iron point, on Twin islands, about two miles (N. 50° W.) from Hidalgo point, a small patch of stratified rocks occurs in which thin limestone layers are numerous, alternating with argillites and quartzites. They frequently contain garnet, pyrite and occasionally a little magnetite, the presence of the last two minerals causing them to weather in brilliant red and in black colours. Their dip is 25° toward the northeast, while their strike is N. 54° W. Some of the limestone beds contain geodes lined with calcite, the formation of which may have been due to the presence of shells. A very imperfect cast of a pelecypod was found in a layer of impure limestone, which, from its convex shape and the character of its ribs and ear, is believed to be the right valve of distorted *Pseudomonotis subcircularis.*

PLATE IX.



(a) Folded argillites, Cordero channel, Maurelle island.

LATE IX.

(b) Ceratites Vancouverensis, Parson bay, Harble-
down island.

Two good casts of this fossil, which are slightly distorted, were found in the small area of sedimentary rocks on the west side of Jumble island, which is situated in Knight inlet near its entrance among the archipelago of Queen Charlotte sound. These rocks are very much altered, as are those of a small stratified mass which lie immediately to the east of Jumble island. At other localities in Queen Charlotte sound small areas of stratified rocks occur which are believed to belong to this series. In general their strike is about 50° W., and their dip is usually vertical or steep towards the northeast. On Swanson island, massive volcanic greenstones are intercalated with argillites, quartzites, and indurated shales. On the southeastern corner of Mars island, on a small unnamed island just north of Bonwick island, on House island, on the outer islet of the Sedge islands, and on the northeastern portion of Village island, small areas of sedimentary rocks are exposed. They consist of argillites, quartzites, and limestone, the beds of which usually range from one to six inches in thickness. Owing to the differential weathering of their layers they present a ribboned appearance. On House and Sedge islands they are intricately folded, while on a small island to the west of Fire island, and in Health bay on Gilford island, what seem to have been the same rocks have been partially changed to hornblende schists. All of these small masses of stratified rocks have experienced the effects of contact metamorphism, and the adjacent plutonic rocks usually contain a large number of small detached fragments of the stratified series. The presence of *Pseudomonotis subcircularis* determines these rocks to be of Upper Triassic age.

## Contact Metamorphism of Sedimentary Rocks.

On the western part of Harbledown island, and on South Valdes island, certain portions of the sedimentary series of rocks approximate more closely to their original character than those in any other localities within the region; but, in general, the stratified rocks have been much altered under the influence of the processes of metamorphism. In many instances important changes in their mineralogical composition have been induced through contact with the intrusive plutonic rocks, while in a molten state. The intrusion of the latter was accompanied by the emission of heated gases, vapours and

waters, some of which were undoubtedly supersaturated solutions that, passing outward into the invaded rocks, caused their partial or entire recrystallization, and often developed new minerals within them. The contact aureole is very narrow in some places, while in others it attains a width of from one to about three thousand feet.

When influenced by contact metamorphism, limestones, in addition to recrystallization, are especially susceptible to the formation of new minerals. Within the contact aureole the [illegible] non-metallic minerals have developed [illegible] the limestones and calcareous rocks of the region.

| | | |
|---|---|---|
| Garnet | Sphene | Sillimanite |
| Wollastonite | Vesuvianite | Tourmaline |
| Tremolite | Hornblende | Serpentine |
| Epidote | Muscovite | Chlorite |
| Quartz | Zoisite | |

The serpentine and the chlorite are products of the alteration of the pyroxene and hornblende respectively.

Of these minerals, the first five on the list are of the most widespread occurrence. In some localities, as on Mars island in Queen Charlotte sound, very much indurated argillites and quartzites alternate with bands that are almost entirely composed of garnets. Prior to metamorphism, these rocks were shales and fine-grained sandstones interbedded with thin layers of impure limestone. A specimen from one of these garnetiferous bands on Mars island, which macroscopically appears to be a closely packed aggregate of cinnamon-brown garnet crystals with a little calcite and tremolite, was found, when examined in thin sections, to contain also small amounts of wollastonite, sphene, sillimanite, and quartz. A specimen from another band displays small crystals of garnet in a white fine-grained matrix, which under the microscope proved to be granular wollastonite with zoisite, quartz, and vesuvianite. On the Elsie mineral claim, on the west side of Redonda island, occurs a small patch of massive limestones that have almost entirely lost their identity through replacement by magnetite, wollastonite, epidote, quartz, and vesuvianite, with secondary serpentine. A few narrow bands of limestone, about one mile before Axe point in Knight inlet, have been

altered to a dark greenish-grey rock, which in thin section is found to consist of hornblende, epidote, sphene, quartz, and calcite. The hornblende is very strongly pleochroic from very dark brownish-green to light olive-green, and is thus distinct from the pyroxene hornblende of the region. Other localities, where contact phenomena of a similar nature may be seen, are, the Twin islands; Bold point, on S. Valdes island; southeast of Granite bay in the interior of S. Valdes island; upper tunnels of Cuba Silver Mining Co. on Loughborough inlet. In the last locality, garnets of a light red colour lie in a matrix of radiating fibres of tremolite. In some places, as in Fanny bay on Phillips arm, or Adeane point on Knight inlet, where crystalline limestone is in contact with the plutonic rocks, it contains siliceous concretions with pyrite, and the whole mass has been stirred about resembling a marbled cake in appearance.

Of all the typical contact minerals, garnet, epidote, and wollastonite seem to be the most abundant. The garnet is light red to brown in colour, occurring as single crystals, aggregates of crystals or in massive form. In thin section, it is colourless or yellowish, and often exhibits anomalous double refraction which bears a definite relation to the faces of the rhombic dodecahedron. The double refraction is variable and occasionally the crystals of garnet display triangular and diamond-shaped patterns, the latter with angles corresponding to the face of a dodecahedron. In each figure the extinction is progressive from the outside towards the centre. Excellent specimens of garnets possessing these anomalous properties were collected on Mars island and on the Twin islands. The garnets contain irregular inclusions of all of the other minerals which may be present. It seems probable that here, as in Alaska, "the greater per cent of the garnet associated with the contact metamorphic deposits is andradite, and not grossularite."[1]

The wollastonite is white or greyish-green in the hand specimen, and usually occurs in grains of very variable size. On the Elsie mineral claim, West Redonda island, it occasionally occurs in fibrous aggregates in which the stout fibres owe their origin to repeated twinning parallel to (100).

[1]U. S. Geol. Surv. Bull. 347, p. 91

Epidote is not restricted in its occurrence to the metamorphosed limestones, but also occurs in some of the altered argillites, and is very abundant as a product of decomposition in the intercalated volcanic rocks. A pale greyish-green rock traversed by thread-like veins of calcite and quartz, which of frequent occurrence, is typically developed near the marble on the mainland south of Dinner rock, and in Bird cove, Reade island, consists of epidote, chlorite, quartz, sphene, and a little calcite. This rock seems to have been a limestone which has been largely changed to epidote through contact metamorphism.

Tremolite occurs in the form of radial aggregates of white, silky fibres. Tourmaline was only noticed to be present in the form of sprays of black, needle-like crystals upon a joint plane traversing crystalline limestone on the Geiler mineral claim in the interior of South Valdes island. In McDonald bay, Knight inlet, muscovite occurs in crystalline limestone at its contact with granodiorite.

Within the zone where the stratified rocks have been affected by contact metamorphism, it is not uncommon to find that they have been impregnated by disseminated grains or masses of pyrite, pyrrhotite, magnetite, chalcopyrite, bornite and, less frequently, by small grains of galena, zincblende, arsenopyrite, and gold.

The manner of their occurrence clearly indicates that these metalliferous minerals were deposited during the cooling down of heated solutions which emanated from the plutonic magmas. There likewise seems to be no reason to doubt that at least a considerable percentage of the non-metaliferous minerals, such as garnet, epidote, wollastonite, etc., were similarly formed by deposition from magmatic emanations. In support of this is the fact that some of the limestones, which have been impregnated by these minerals, are remarkably pure. A sample of limestone belonging to the Marble Bay Formation, from South Valdes island, was found to contain a little more than one per cent of insoluble residue in the form of excessively fine particles of quartz.

Within the contact aureole the argillites and quartzites either become very compact, with a highly indurated appearance, or they develop a schistose structure. In a few locali-

ties they were noticed to contain visible epidote and garnet. In thin section, their original clastic or granular character is no longer discernible, but they are found to consist of a mosaic of exceedingly small interlocking grains of quartz, often accompanied by small amounts of epidote and irregular grains of magnetite and pyrite. Every stage in their transition to quartz-biotite schists and quartz-hornblende schists may be observed in the field. Ferro-magnesian minerals, usually flakes of biotite, develop in perfect alignment within the marginal portions of a layer of argillite. These appear as dark lines in the rock, and, becoming more and more numerous, a schist is finally produced. In only two localities, at Fawn bluffs in Bute inlet, and at Wignell point in Loughborough inlet, narrow bands of slate occur, which are also probably metamorphic equivalents of the argillites. Of those minerals which are frequently developed in argillaceous rocks through contact metamorphism, andalusite was observed in a thin section of a quartz-biotite schist from Port Neville, which also contains augite, a little epidote and a few grains of magnetite. The homogeneous texture and pure siliceous character of some of the cherty argillites suggests that they may have been formed by metasomatic silification of thin limestone layers.

The extrusive and intrusive volcanic rocks apparently have been altered to schists more easily than the other members of the stratified series. As in Port Neville, and in the vicinity of Hall point, on the north shore of Maurelle island, they are partially represented by hornblende schists which are intercalated with the less altered argillites. These schists, or amphibolites, consist chiefly of hornblende and plagioclase feldspar, with such minerals as epidote, chlorite, kaolin, quartz, sphene, and black iron ore. Certain roof-pendants composed of hornblende-schists, such as the one which occurs about a mile beyond Cascade point in Knight inlet, are believed to be the metamorphosed equivalents of massive volcanics, probably belonging to the Valdes formation. Schists of this type are similar in their mineralogical composition and general appearance to those which have been formed by the local shearing of the diorites in the region.

In general it may be said that the development of typical contact minerals in the sedimentary rocks is dependent upon

the depth to which the roof-pendants have been exposed. The best examples of the effects of contact metamorphism are limited to some of the islands and lower forelands, where denudation has not been carried to such a great depth as in those fiords of the mainland which are bordered by the highest mountains. Within the latter, depths are exposed where metamorphism has been so intense as to almost completely alter the stratified rocks to schists with intercalated lens-like bodies of crystalline limestone. New minerals have been developed but the metamorphism has been more closely related to that which takes place in the zone of flowage within the crust of the earth. The magma, at this depth, was under greater pressure, and the invaded rocks more impermeable, two conditions which are not conducive to the release of magmatic emanations. Since, apart from the variable character of the solutions emitted by the cooling magmas, the conditions which were suitable for the formation of mineral deposits of economic value were identical with those necessary for the development of the typical non-metaliferous contact minerals it may be expected that within those portions of the district where the fiords have been eroded to greatest depth (viz., where they are bordered by the higher mountains), if such deposits occur, they will be found within the roof-pendants of stratified or schistose rocks, but up toward the tops of the mountains rather than at the lower levels.

## Upper Jurassic (?)

### COAST RANGE INTRUSIVES

The intrusive igneous rocks of this region include (i) the abyssal or plutonic rocks, which have invaded the stratified series in the form of immense batholiths, and (ii) the hypabyssal varieties, which, as dykes, traverse both the plutonic and stratified rocks, occasionally spreading out along lines of stratification in the form of sheets.

### ABYSSAL ROCKS.

*Distribution*

More than three-fourths of the area covered by this report is underlain by plutonic rocks, which are exposed at the sur-

face over wide areas or are locally covered with a thin mantle of glacial drift. They not only comprise the major portion of the Coast Range within this district, but also the majority of the off-shore islands. The small areas of stratified rocks are mere remnants of the roof which once universally covered these batholiths, there being no doubt that they are resting upon plutonic rocks of the same petrographical character and geological age as those about to be described. The walls of the fiords, which penetrate far into the central portion of the Coast Range where mountains occasionally rise to eight thousand feet in altitude, present an almost continuous outcrop of these rocks, which once existed in a liquefied or molten state. Along the upper reaches of the fiords, the roof under which this magma cooled and crystallized must have been situated many thousands of feet above the summits of the loftiest mountains of to-day.

### *Lithological Character*

The petrographical character of these rocks should be of especial interest because of their geological importance within this area. They are heterogeneous in character, including granites, granodiorites, diorites, gabbros, and hornblendites among their number. Such a close petrographical relationship exists between the different types that, within comparatively small areas, one variety gradually passes into another. The following rock-types were examined:

Biotite and hornblende granite
Biotite-muscovite granite
Granodiorite
Diorite
Quartz diorite
Quartz-mica diorite
Quartz-augite-diorite
Quartz-norite
Hornblende gabbro
Porphyritic olivine-hornblende gabbro
Hornblendite

In respect to areal distribution they vary widely in relative importance. Quartz diorite is the most prevalent type, although the granites and granodiorites, if considered together,

are probably as abundant. Gabbros and hornblendites occupy relatively small areas.

As a rule, these rocks possess a remarkably uniform granitoid texture, usually being of an evenly coarse-grained character. The basic varieties are subject to a more frequent change in texture than the acidic, medium-grained species being common among them, while the hornblendites are the most coarsely crystallized of the series. Porphyritic facies have been developed in some of the small intrusive rock bodies (as in the vicinity of Deep bay), along zones of irregular width at the margin of some of the batholiths, and over limited areas where erosion has removed the roof but apparently has not reduced the surface of the batholith to any great depth. The majority of the phenocrysts are plagioclase, although those of orthoclase and quartz are locally developed among the acidic rocks, and, less often, those of hornblende among the basic. A miarolitic structure was noticed within these rocks in but two places—in granite, on the south shore of Ramsay arm about three miles from its entrance; and in diorite, on the west shore of East Redonda island at a point nearly opposite to Marylebone inlet. In the former locality, a few drusy cavities, up to four inches across, are lined with small, well-formed crystals of orthoclase, oligoclase and quartz; in the latter, crystals of hornblende protrude into small hollow spaces. These cumulative facts seem to imply that the conditions under which the greater portion of these rocks crystallized were unusually uniform in character.

In general, they are some shade of grey in colour, the most acid varieties being almost white, and with increasing basicity becoming darker until the hornblendites are quite black. In a few localities the granites and granodiorites are of a pink or red hue, owing to the colour of their feldspars, while greenish tints characterize some of the darker rocks, chiefly because of the development of chlorite or epidote or both of these secondary minerals. Occasionally minute veinlets of epidote and chlorite traverse these rocks. Upon weathered surfaces the shades of green and white have frequently been accentuated, the blending and alternation of rocks of sombre colours with those which are lighter constituting one of the most pleasing features of the scenery.

The mineralogical composition of these rocks may be conveniently shown by arranging the component minerals in a tabulated list, as follows:—

| *Essential* | *Accessory* | *Secondary* |
|---|---|---|
| Plagioclase | Plagioclase | Hornblende |
| Orthoclase | Quartz | Chlorite |
| Quartz | Microcline | Epidote |
| Hornblende | Hornblende | Zoisite |
| Biotite | Muscovite | Kaolin |
| Augite | Sphene | Calcite |
| Hypersthene | Apatite | Muscovite |
| Olivine | Magnetite | Sericite |
| | Pyrite | Bastite |
| | Titaniferous Iron Ore | Talc |
| | Zircon | Leucoxene |
| | Epidote | Magnetite |
| | Orthite | Pyrite |
| | Pleonaste | |

A comparison of this table with a similar one which was compiled by LeRoy,[1] in order to depict the composition of these plutonic rocks as they occur in the adjacent area to the south, will show that only five minerals have been added to the list, viz., microcline, olivine, talc, pleonaste, and orthite. These minerals are of rare occurrence within this district, the mineralogical composition and petrographical character of the rocks being essentially the same as in the area described by him.

Five minerals constitute more than ninety per cent of the total mass of plutonic rocks in this region, and apparently their relative abundance may be expressed by the formula—plagioclase>hornblende>biotite>quartz>orthoclase. Of the remaining primary minerals, those of frequent occurrence are sphene, muscovite, apatite, and the iron ores.

These rocks possess numerous family traits in common, one type passing into another, suggesting that they were all derived from a magma which was, at least approximately, homogeneous in character. Considering them as a whole, the following mineralogical characteristics may be noted:—

[1]Geol. Surv. of Canada, Bull. No. 996, 1908, p. 19.

(1) The soda-lime feldspars are far in excess of the potash varieties, the latter being most abundant in the acidic rocks, although in some of the rocks possessing the largest percentage of free quartz, plagioclase is more abundant than orthoclase. From determinations of the plagioclase feldspars in a large number of the rocks, it would seem that their average composition is that of a slightly acid andesine. Oligoclase and andesine are the most abundant varieties, although albite is quite often present in the acidic and labradorite in the basic rocks. Bytownite and anorthite are rarely met with, occurring in only a few of the most basic rock-types. Zonal structures are very often displayed in the individual crystals of feldspar, especially by those of andesine and oligoclase. The boundaries between the successive zones are commonly very distinct, showing a repeated and sharply defined alternation in the growth of sodic and calcic varieties; but frequently a progressive extinction, shading from the interior of a crystal outwards, or vice versa, suggests that the change in molecular constitution has been as gradual as the growth of the crystal. Albite twining is almost invariably present, and is very often associated with twinning according to the carlsbad and pericline laws. The width of the twinning lamellae generally is greater among the more basic feldspars, which are often of a very dark grey colour because of the multitude of minute inclusions of black iron ore which they contain. Among the specimens which were examined microscopically, microcline was only noticed to be present in the granite from Granite mountain on Bute inlet. Epidote, zoisite, calcite, kaolin and sericite are very common products of the decomposition of the feldspars.

(2) Quartz is present in nearly all of these rocks, being absent from only a few of the most basic varieties.

(3) The amphiboles are represented by common green hornblende, whose pleochroism ranges from a pale yellowish-green to dark green. This mineral usually occurs in the form of small greenish-black prisms, upon which crystal faces are seldom seen, but, possessing an excellent cleavage, smooth glistening surfaces are much in evidence. In the hornbleadites, blade-like crystals of hornblende sometimes attain a length of two or three inches. Some fragments of these

large crystals of hornblende were carefully selected from a specimen of hornblendite, which was collected about two miles beyond the Ahnuati valley on the north shore of Knight inlet, and Mr. W. B. Campbell, B.Sc., while a fourth year student in the course of Chemical Engineering in McGill University, made an analysis of this mineral with the following results:

| | | | |
|---|---|---|---|
| $SiO_2$ ............ | 41.0 | $CaO$ ............ | 11.6 |
| $Al_2O_3$ ............ | 14.6 | $MgO$ ............ | 13.2 |
| $Fe_2O_3$ ............ | 4.1 | $K_2O$ ............ | 0.4 |
| $FeO$ ............ | 10.5 | $Na_2O$ ............ | 2.7 |
| $TiO_2$ ............ | 2.7 | | |
| | | Total ............ | 100.8 |

An analysis of a specimen of hornblendite, taken from an occurrence of this type of rock on the east side of Bute inlet, just beyond Fawn bluffs, was made by Mr. R. P. D. Graham, lecturer in Mineralogy at McGill University, with the following results:—

| | % | | % |
|---|---|---|---|
| $SiO_2$ ............ | 44.20 | $CaO$ ............ | 11.83 |
| $Al_2O_3$ ............ | 27.37 | $MgO$ ............ | 2.78 |
| $Fe_2O_3$ ............ | 2.71 | $K_2O$ - $Na_2O$ ...... | 2.88 |
| $FeO$ ............ | 6.58 | Ign. ............ | 1.08 |
| $MnO$ ............ | trace | | |
| | | | 99.43 |

Among some of the dark coloured rocks, the hornblende assumes both compact and fibrous forms, having the appearance of "green diallage." Such hornblende is actinolitic or smaragditic in character, or, when compact, has a mottled appearance under the microscope, because the intensity of the green colour varies not only in different crystals but often within a single individual. The lines of cleavage are closer together than in ordinary hornblende and minute particles of black iron ore are profusely sprinkled along them. Fibres of hornblende, singly or matted in aggregates, pierce the feldspars in every direction. In many specimens containing hornblende of this character, no diallage is present; but a few rocks were examined in which a small amount of this mineral occurs in such relationship to the hornblende as to

make it plain that processes of uralitization have been at work.

Biotite and hornblende very frequently occur together, often being mutually intergrown.

(4) Biotite occurs more commonly in the light coloured, acidic rock-types than in the dark basic varieties. When present in the latter, it is usually subordinate in amount to hornblende. Along the upper reaches of Knight and Loughborough inlets, biotite seems to be more abundant than the other ferro-magnesian minerals. Microscopically its flakes are dark brown to black in colour and occasionally have perfect hexagonal outlines. Under the microscope, they are very strongly pleochroic, from dark brown to light yellowish brown. Hexagonal flakes of this mineral, of an almost equal size, are disseminated through the granite from a point about two miles before Matsatu valley in passing up Knight inlet, imparting an unusual appearance to this rock. Chlorite is the common product of decomposition of both the biotite and hornblende. When alteration to chlorite has taken place, small grains of secondary magnetite have often separated out.

(5) In a discussion of the general mineralogical composition of these rocks, the pyroxenes are of minor importance when compared with hornblende or biotite, since their occurrence seems to be restricted to a few of the basic varieties. The diallage is colourless or pale yellow in thin sections, and is generally found to be largely altered to uralitic varieties of hornblende. It is believed by the writer that this mineral was once of more widespread occurrence in these dark rocks, but to-day its former presence is recorded by that of secondary hornblende. Probably this change of diallage into hornblende has been produced by the hydrothermal action of mineralizing gases and vapours which were liberated during the cooling down of the intrusive magma of the batholiths. Hyperstheme was only noticed to be present in the quartz-norite from Baker island, which is described in detail on page 90.

(6) Sphene is apparently present in the majority of these rocks. It occurs either in the form of irregular grains or in small crystals with the characteristic wedge-shaped outline. It is surprising how often its bright little yellowish-brown crystals are discernible to the naked eye.

Microscopic crystals of zircon are disseminated through some of the granites, granodiorites and quartz-diorites. Apatite is almost universally present in the form of small hexagonal crystals or irregular grains of microscopical dimensions. Small grains of black iron-ore are sprinkled through all of these rocks, but their number is exceedingly variable. They are occasionally surrounded by a thin border of leucoxene. The presence of pyrite is frequently betrayed by the development of rusty patches or zones, which have been produced by its oxidation on surfaces of weathering. In the vicinity of contacts between older and younger bodies of intrusive plutonic rocks, the older are often impregnated with more or less pyrite.

In the specimens examined, the occurrence of olivine is limited to the dolerite from Hernando island, which is fully described upon a later page. Allanite is abundant in the pink granite from Dean point on West Redonda island. It is brownish-green in colour, strongly pleochroic, and is associated with epidote. This latter mineral is present in many of these rocks, usually being derived from the decomposition of the feldspars, although in a few granites it seems to be pyrogenetic. Pleonaste occurs in a dark hornblende-gabbro, which is exposed on the eastern side of the entrance to a salt lagoon on the south side of Cortez island. When this rock is examined under the microscope in thin sections, the pleonaste appears as a mineral of a beautiful dark green colour surrounding the grains of magnetite.

*Uncommon Types.*

A few varieties of plutonic rock, which are not typical of this district as a whole, but are interesting because of certain peculiarities of structure, composition or occurrence, seemed worthy of a more careful study. They illustrate either some exceptional order in the separation of the rock-forming minerals from a cooling magma, or some extreme products of differentiation which are not of common occurrence within the batholiths of the Coast Range.

(1) *Quartz-Norite.* This type of rock occurs along Indian passage on the northern shore of Baker island in Queen Charlotte sound. It is of interest in connexion with a description

of this area, because it is the only locality in which the presence of a rhombic pyroxene was detected. In itself the rock is remarkable for the unaltered condition of its component minerals, the dark colour and opaque character of its feldspar, and for the intergrowth of its hypersthene and augite.

It is a coarse-grained rock with a uniform greyish-black colour and a hypidiormorphic structure. Megascopically, it is difficult to distinguish between the plagioclase and the pyroxene, because of their striking similarity in colour, but the plagioclase assumes the form of narrow laths, up to 4 cm. in length, possessing glancing cleavage surfaces upon which twinning striations may often be observed, while the pyroxene occurs in small irregular grains with less perfect cleavage.

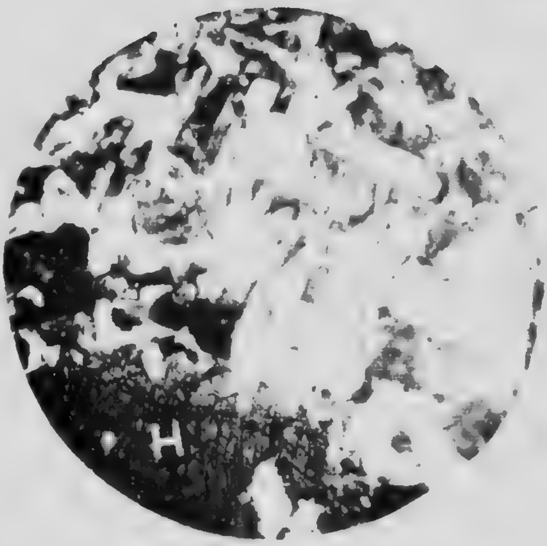
By the method described below,[1] a photograph was made in which the thin section was magnified five diameters. By lines drawn one-tenth of an inch apart, this photograph was divided into squares, and by counting the squares it was determined that approximately two-thirds of the rock is composed of plagioclase

The constituents revealed by the microscope are (1) feldspar, (2) faintly pleochroic rhombic pyroxene (hypersthene), (3) monoclinic pyroxene (diallage), (4) biotite, (5) hornblende, (6) quartz, and (7) iron ore. The feldspar is chiefly andesine ($Ab_1An_1$), with a small amount of labradorite ($Ab_2An_3$). Its cloudy appearance in thin section is due to the presence of innumerable dust-like particles, or a matted sagenite-like network of fine rods or plates which represent, in all probability, titaniferous iron ore (ilmenite). The rods always have a definite arrangement, most frequently following the direction of the double twinning after the pericline and albite laws.

The amount of diallage is less than that of the faintly pleochroic hypersthene. These two minerals are intimately

[1]Several of the photographs of thin sections in this report were prepared in the following manner:—The thin section is placed in the same position as a negative in an enlarging camera. Using an electric arc as the source of illumination, the image is cast upon a photographic plate. An exposure of only a few seconds is required before the plate may be developed. Such a procedure permits one to enlarge the *whole* of a thin section to a size corresponding to the scale desired.

PLATE X.




(a) Photomicrograph of [illegible]. H, hornblende. The [illegible] section displays the progressive [illegible] of the felspar.


[illegible] Pho[illegible] [illegible] showing intergrowth [illegible] [illegible] A [illegible] H hypersthene. P. [illegible]

intergrown with each other (see Plate X (b)), and sometimes the non-pleochroic diallage forms a partial border about the hypersthene. The incipient alteration of the hypersthene is marked by the development of a small amount of bastite. Hornblende is a constituent of insubordinate importance, its presence probably being due to uralitization. It chiefly occurs as flecks which are sprinkled through the augite. Iron ore is quite abundant in the form of irregular grains, which are surrounded by an irregular fringe of dark brown biotite. A small amount of quartz is present in the angular interstices between the xenomorphic crystals of feldspar. The constituents of this rock crystallized in the following order:—iron ore, biotite, the feldspars, the pyroxenes, hornblende, and quartz.

(2) *Quartz-Diorite.* Specimens of this rock were collected on a small stream, called Gold creek, at a distance of about one hundred yards from where it debouches into the sea on the northern shore of Call creek. The intrusive rock-body from which these specimens were taken has the form of an irregular sheet-like apophysis which, dipping gently to the east, penetrates other plutonic rocks. Megascopically this rock is characterized by the presence of numerous subhedral crystals of hornblende, up to an inch in length and three-tenths of an inch in width, scattered through a matrix which in appearance resembles a mixture of salt with a small amount of pepper. The black hornblende crystals, which in vertical sections display a tendency to assume a bi-convex form, are sprinkled with many white specks which are visible to the naked eye.

Under the microscope, the rock proves itself to be worthy of especial mention on account of (1) the remarkable poikilitic structure exhibited by the hornblende, and (2) the progressive undulatory extinction of the greater number of the individuals of plagioclase (Plate X (a)). In thin section, the hornblende is strongly pleochroic from a deep olive-green to a light yellowish-green. It encloses a vast multitude of lath-shaped crystals of plagioclase, which are of a smaller size but of a similar composition to those of which the matrix is largely composed. The hornblende also contains grains of iron ore, the latter mineral occasionally occurring as very minute particles which are arranged in patterns similar in

nature to those produced by dendritic growth. The hornblende is undoubtedly a primary constituent, and it is slightly altered to chlorite.

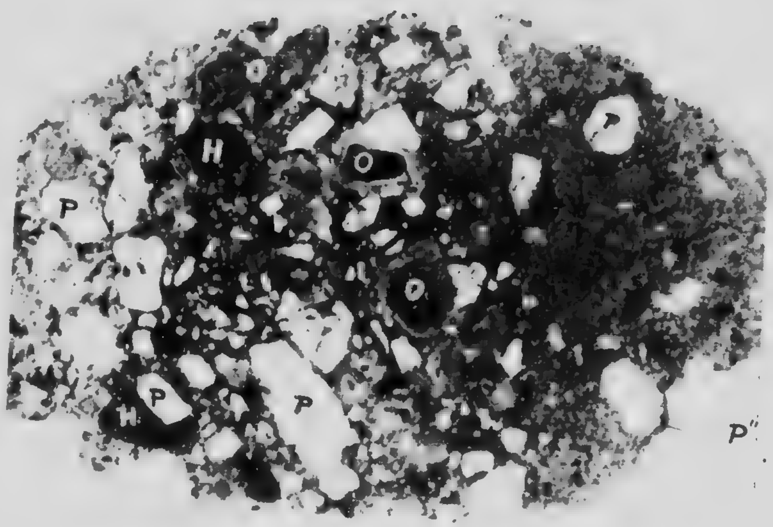
The matrix is essentially composed of plagioclase with smaller amounts of titanic iron ore, quartz, sphene, apatite and secondary epidote, zoisite and leucoxene. The plagioclase is chiefly oligoclase, with which is associated a certain amount of albite. It occurs in the form of stubby laths which display zonal structures and, with exceptional frequency, a twinning according to the Carlsbad as well as the albite law. The undulatory extinction, from outside inwards, may be due to a zonary growth which is so fine that it is not revealed by the microscope. The central portions of some of these crystals of plagioclase have been altered to epidote and zoisite.

The iron ore occurs in considerable quantity as large grains, which are disseminated through the light-coloured minerals and produce the pepper-and-salt appearance in the hand specimens. The quartz crystallized last, and is very irregularly distributed. Thick prisms of apatite and small anhedral crystals of sphene are sparingly present.

During the crystallization of this rock, the feldspar crystals first began to form, but their growth was interrupted at certain centres by the development of hornblende. There does not seem to have been two generations of the plagioclase, but a progressive growth of the crystals of this mineral took place in the matrix, while some individuals which were not fully grown became enclosed within the hornblende.

(3) *Porphyritic Hornblende-olivine Gabbro.* At Hidalgo point, on the northeastern corner of Hernando island, a small area of the bed-rock emerges from beneath the sands of which the greater part of the island is composed. Here a contact between quartz diorite and a small patch of stratified rocks has been exposed. Near the most southern extension of this contact, a later intrusion has given rise to a rock type which, from a petrographical standpoint, is one of the most interesting of those observed within this region. This intrusive body of rock assumed the form either of a very wide dyke, or of a small stock, the margin of which is laid bare.

PLATE XI.

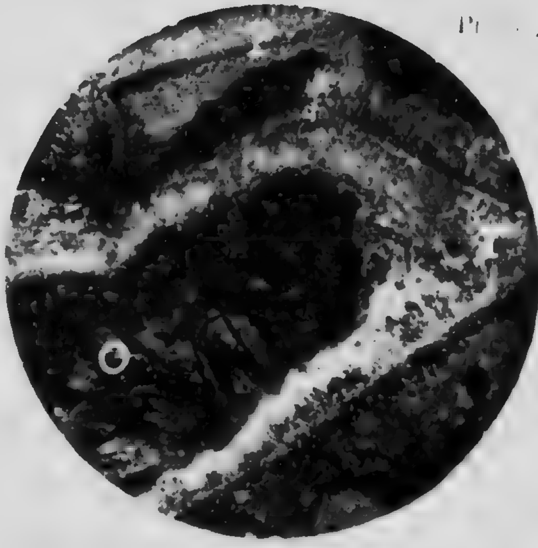



(a) Photograph of thin section of porphyritic hornblende-olivine gabbro, near Hidalgo point, Hernando island. Magnified 5 diameters. O, olivine; H, hornblende; P, plagioclase.

PLATE XI.

(b) Photomicrograph of Baveno twin in rock shown in Plate XI (a).

PLATE XII




(a) O, olivine altered to serpentine and black iron ore; P, plagioclase; T, talc.


(b) O, olivine, bordered by talc and black iron ore; P, plagioclase; T, talc and black iron ore.

PHOTOMICROGRAPHS OF ROCK IN PLATE XI (A), SHOWING THE BORDERS OF TALC ABOUT THE DECOMPOSED CRYSTALS OF OLIVINE.

At the immediate contact, this rock is fine-grained, but at a distance of a few inches within the mass large phenocrysts of hornblende, which occasionally exceed an inch in length and width, and smaller ones of plagioclase, augite and olivine, are abundant in a fine-grained groundmass. A foot from the contact the groundmass becomes quite coarsely crystallized, and of a distinctly gabbroid character. On a fresh surface the rock is a very dark grey in colour and the bright cleavage surfaces of the phenocrysts impart to it a striking appearance.

The specimen examined in the laboratory was collected at the contact of this porphyritic rock with the diorite. As a hand specimen it should be called a porphyritic hornblende-olivine diabase, but the author has deemed it advisable to substitute the term gabbro instead of diabase when referring to the large and more coarsely crystallized mass of which this fragment merely represents a marginal facies.

The phenocrysts are more or less angular or rounded in form. Their appearance strongly suggests that at least some of them were developed as idiomorphic crystals, which were then brecciated (Plate XI (a)) by movements within the magma. Their rounded forms and deeply embayed borders imply that, owing to some chemical or physical change in the magma which gave them birth, they have been partially dissolved.

Olivine is abundant, but is very much decomposed, the alteration products being talc, serpentine and an unusual amount of magnetite, together with some pyrite. The crystals of olivine are surrounded by a narrow kelyphite-like rim of talc, the laminae of this secondary mineral being developed normal to the exterior surface of each crystal. When the olivine adjoins the feldspar this zone is wider, and in a few instances a double fringe of talc has been formed. The interior of some of the phenocrysts is fresh, but usually the cracks which traverse the greyish-green olivine are lined with fibrous or lamellar serpentine. In a few instances, the olivine has been entirely replaced by these products of decomposition, a core of bright green serpentine, traversed by veinlets of magnetite and pyrite, being surrounded by a border of colourless talc in which very small grains of magnetite are disseminated (Plate XII, (a) and (b).

Under the microscope, the phenocrysts of green hornblende often display a poikilitic structure owing to the inclusion of stubby laths of feldspar. They are bordered by a narrow absorption rim. The individuals of pale-green augite are numerous though not so large as those of hornblende. Occasionally they assume the form of idiomorphic crystals and are frequently surrounded by a zone of uralitic hornblende.

The abundant phenocrysts of feldspar assume either anhedral or subhedral forms. They approximate very closely to labradorite in composition, the majority of them being of a slightly more acidic character. This labradorite is remarkable for its unaltered condition and for the various habits of twinning which it exhibits. In a single thin section, twinning has developed, within the individuals present, according to the Carlsbad, albite, pericline and Baveno laws (Plate XI (b). In some phenocrysts the twinning lamellae are very narrow, while in others they are far apart. Strain shadows are not uncommon. Many of the crystals are traversed by irregular cracks, some of which have been formed by an increase in the volume of the rock consequent upon the hydration of the olivine, but others were undoubtedly broken before the magma had solidified—probably while being transported from a lower level.

The texture of the rock as a whole is porphyrito-granular, but the groundmass shows a tendency to develop the ophitic structure. This groundmass is composed of plagioclase and augite, with a large amount of iron ore, a few needles of apatite as accessory constituents and some secondary hornblende and pyrite. The plagioclase occurs in the form of equidimensional grains or short laths, which occasionally display a zonal growth. In composition they correspond to a basic oligoclase.

(4) *Orbicular Hornblende-Gabbro.* In his report for 1887, while describing the geology of the islands in Queen Charlotte sound, Dawson writes as follows:—"Dark highly hornblende rocks, of granitoid texture, also appear in several "places, and these might appropriately be classed as diorite "from their external appearance. On one of the small islets "west of the end of Midsummer island, a dark rock assumes "a beautiful spheroidal concretionary structure which is well

"shown on glaciated surfaces. The spheroidal masses are "closely crowded together, their diameter being from two to "four inches." A more detailed description of this rock is now given, because (i) it displays an exceptionally perfect development of the orbicular or spheroidal structure, and (ii) certain peculiar features attend its occurrence, which, in so far as the writer has been able to ascertain, have not been found in other localities where spheroidal structures are known to be developed among plutonic rocks.

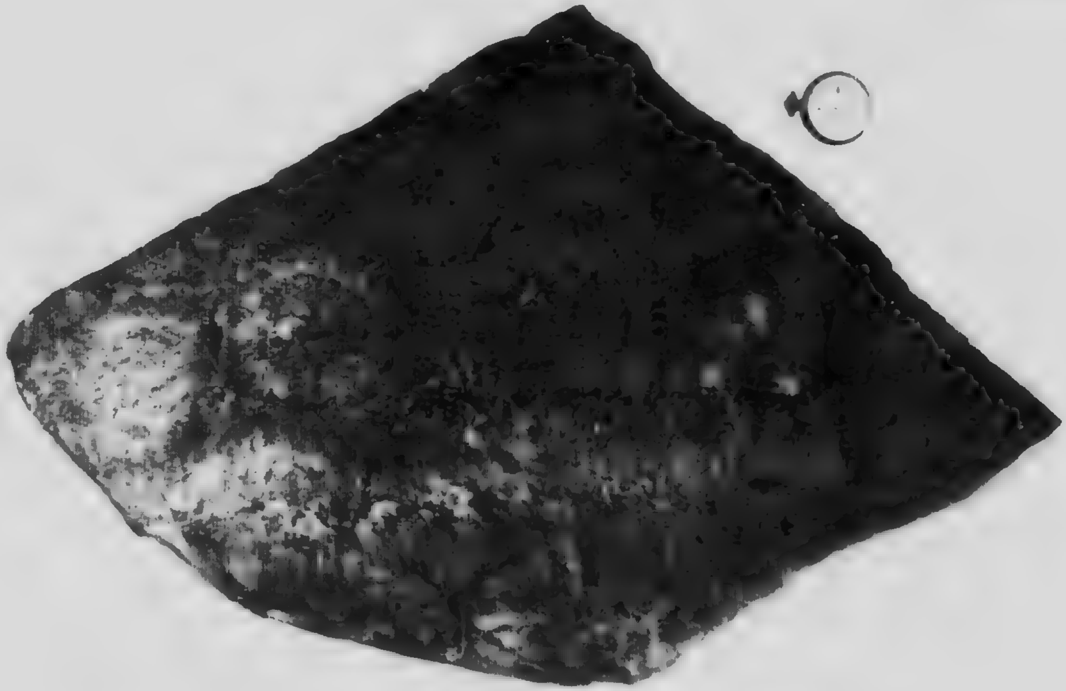
The greater part of this islet and of the immediately adjacent islands is composed of dark basic rocks, which vary both in their composition and texture and are frequently penetrated by apophyses and dykes of granite. These basic plutonic rocks seem to be a differentiated marginal facies of the batholith of granite from which very many of the islands in Queen Charlotte sound have been carved by the activity of the long-enduring processes of erosion. On the northwestern corner of the small island where this orbicular gabbro occurs, a small patch of argillites, with an areal extent of only a few square yards but with the ribboned appearance and vertical dip which characterizes a roof curtain of these rocks in this region, is situated at a distance of about one hundred yards from the place where the plutonic rock exhibits the spheroidal structures. The location of this small area of sedimentary rocks makes it plain that the conditions necessary for the crystallization of the magma into spheroidal aggregates of rock-making minerals existed at a short distance, in a horizontal direction, from an actual contact. Moreover, it seems probable that in this locality the batholith has not been deeply denuded, and, hence, the roof, or some pendant from it, may have been removed not far above the present surface.

The smoothly glaciated surface of the outcrop of this spheroidal rock has been exposed for a sufficient length of time to permit the action of the weather to etch those minerals most readily decomposed, and to thus bring into relief macrosopic structures which are not easily discernible upon a freshly fractured surface. A heavy fog was slowly lifting at the time the writer visited this locality, and the wet surface of this outcrop presented an exceedingly striking appearance.

That portion of the intrusive body of rock, which [illegible] tinguished by the development of the orbicular structure [illegible] length, in a north and south direction, of fifty-five feet, [illegible] width is fifteen feet, the western and south[illegible] boundaries being completely exposed, while to the east [illegible] north it is partially masked by a thin covering of soil which bears a lowly growth of shrubbery. Within the area thus outlined the orbules are so closely congregated that they are contiguous with each other. Within a distance of twelve feet from the southern end of this colony of spheroids, the gabbro passes gradually into a normal state of crystallization. The transitional type of rock is characterized by a tendency on the part of the feldspar to gather itself into rounded aggregates, about an inch in diameter, while the dark ferromagnesian minerals are arranged in an irregular manner around these embryonic light-coloured spheroids. Some orbules of a larger size, which are ellipsoidal in shape, are scattered through the rock, even where it has assumed a coarsely crystallized granitoid texture. They are few in number, being widely separated from each other. One of these [illegible] ellipsoids was noticed to have a maximum diameter [illegible] es. The western margin of the orbicular fa[illegible] is sharply outlined by a black streak or band [illegible] an minerals, which is more or less continuou[illegible] of about an inch.

In so fa[illegible] be determined from an examination of hand specimens, the normal facies of this rock consists of a coarsely crystallized aggregate of dark-grey plagioclase feldspar, a greenish-black hornblende, some black iron ore and pyrite. The rock possesses a hypidiomorphic structure, but it displays abrupt variations in the size of the grains and the relative abundance of its component minerals. In general, the feldspar is the predominant mineral, but in some specimens the hornblende is more abundant. The cleavage faces of both the feldspar and the hornblende are occasionally an inch and very frequently half an inch across. Some of the plagioclase has a striated appearance, owing to the excellent twinning of this mineral according to the albite law. The specific gravity of this rock is 2.95.

PLATE XIII.



Specimen of orbicular hornblende gabbro [illegible]

When examined in thin sections under the microscope no other primary minerals than those already mentioned are found to be present in the normal facies of this rock. The hornblende has every appearance of having been formed by the alteration of diallage. When compact, the hornblende contains a multitude of minute grains of black iron ore. The presence of these dust-like inclusions imparts to it a highly schillerized appearance. Neighbouring crystals differ in the amount of dust they contain, while a single crystal is often mottled or blotched because of the irregular distribution of these inclusions. Occasionally the hornblende possesses the leaf-like structure parallel to a pinacoidal plane and the schillerization along this plane, which are characteristic properties of diallage. Much of the hornblende occurs in the form of actinolite and smaragdite, the more compact variety being occasionally bordered by a fringe of this latter mineral. The actinolite ranges from bright green to colourless varieties, its formation being associated by the separation of a considerable amount of iron ore. The fibrous hornblende pierces the feldspar in every direction. Within a single crystal of feldspar, either the fibres are matted together or small bundles of them persist in following a certain direction, or they are scattered separately in an irregular manner through the crystal. The most of the hornblende is strongly pleochroic in various shades of green, the smaragdite changing from a light yellowish to a beautiful bluish green. The maximum extinction angle of the hornblende is 18°. Decomposition of this mineral accounts for the presence of a small amount of chlorite. The black iron ore is present in fairly large grains, some of which have been altered to pyrite. The presence of a thin border of leucoxene around some of the grains implies that the iron ore is titaniferous.

The majority of the grains of plagioclase are anhedral, but occasionally they display a tendency to assume idiomorphic forms. They are very fresh, though occasionally clouded by the presence of a vast number of excessively small particles of black iron ore. All of them show twinning according to the albite law, the pericline twinning often accompanying it. The high extinction angles of the twinned lamellae, with a maximum of about 40°, determine this feldspar to be a very basic plagioclase. By using Wright's method for the deter-

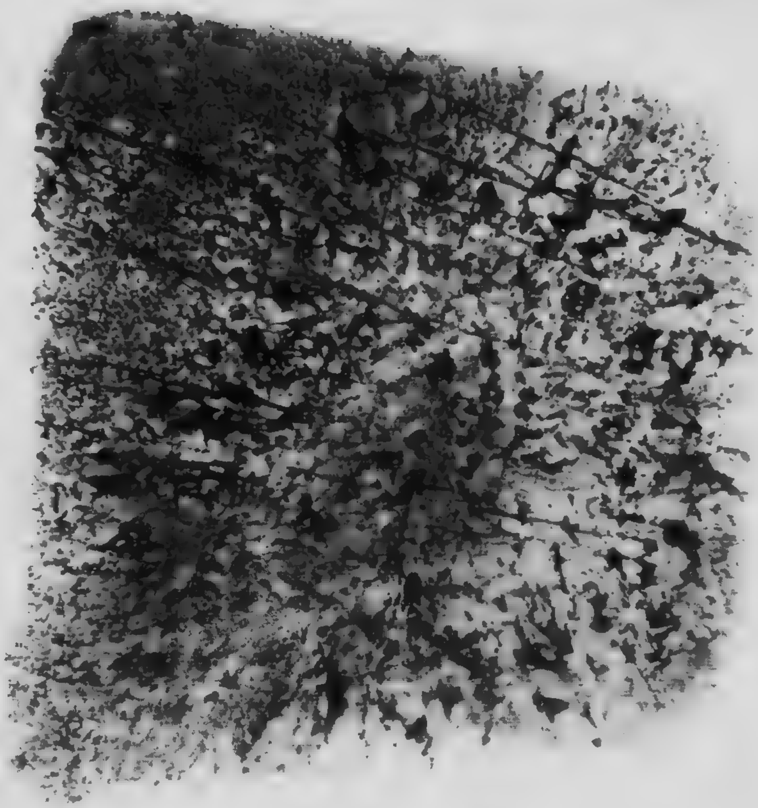
mination of feldspars, it was found that the dominant variety is bytownite ($Ab_1An_3$), with a less amount of labradorite ($Ab_2An_3$). Some of the crystals are traversed by cracks, and are slightly granulated on their borders. The minute fragments are either cemented together by neophytic feldspar or they are surrounded by actinolite. Many of the larger grains possess an undulatory extinction, imposed upon them by the conditions of strain which produced the cataclastic structure.

In the nine thin sections of this rock which were examined, unaltered diallage was only found to be present in one which passed through the central portion of an orbule (Plate XIV). Each rounded crystal of this mineral is bordered by smaragditic hornblende. Although the mineral constitution of this rock might lead one to call it a diorite, the secondary nature of the hornblende and the presence of even this small amount of diallage, which is partially uralitized, suggest that the term hornblende-gabbro may be an appropriate name for it.

In thin sections of the above mentioned transitional type of rock, over which one passes upon approaching the orbicular facies of the gabbro from the south, it is found that the small light coloured nodules are composed of basic plagioclase with some pale-green, fibrous hornblende. The close mineralogical resemblance which they bear to the central parts of the large orbules, and the tendency of their component minerals to arrange themselves in a radial manner give emphasis to the conclusion that they represent an early stage in the development of the orbules. These orbicular nuclei are usually separated from each other by a distance of at least one inch. The remainder of the rock is largely composed of hornblende, similar to that which occurs in its normal facies, accompanied by a few small crystals of highly pleochroic biotite, iron ore and some feldspar. Here and there, chlorite has been formed by the decomposition of these ferro-magnesian minerals, and during the process a little titanite has crystallized out. The dark border, which so sharply defines the western boundary of the orbicular facies of the gabbros and seems to be a unique feature about this occurrence, consists chiefly of hornblende and iron ore with a very small amount of plagioclase.

Differential weathering of the light and dark constituents, the strong contrast in their colour and a regularly arranged

Plate XIV



Photograph of a large thin section [illegible]

variation in the texture contribute to the prominent appearance of the orbicular structure upon the weathered surface of the gabbro. Upon an artificially polished surface, the details of this structure are also beautifully displayed. The orbules generally have the form of perfect spheres, but a few of them have a tendency to assume an ellipsoidal shape. They vary from two to four inches in diameter, although within an area of two or three square feet they are usually of a uniform size. Their outline is sharply defined because they possess a coating, about half an inch thick, which is much finer in grain than the remainder of the rock. Upon a weathered surface these dark-grey fine-grained borders rise in cameo-like relief, thus depicting clearly the exact boundary of each orbule. It is, however, impossible to separate a whole nodule from the rest of the rock, as may be done in several well-known occurrences of orbicular rocks, such as those of Pine Lake in Ontario, Wirvik and Kortfors in Finland, because the crystals upon the margin of these outer envelopes are intergrown with those which occupy the interorbicular spaces. Within these rims, the orbules become lighter in colour and more coarsely crystallized toward the centre. They display a tendency toward both concentric and radial structures, dependent upon the arrangement of the light and dark minerals. In some of the larger orbules there is a well-defined zone, at a distance of about an inch from the centre, which is marked by the presence of a higher percentage of the dark ferromagnesian minerals.

The interorbicular spaces are dark in colour. In the larger spaces the rock possesses a texture which is similar to that of the normal facies, being largely composed of hornblende with small amounts of plagioclase and iron ore. The smaller ones are characterized by the presence of feldspar crystals, up to half an inch in length, which, in section on a polished surface, are arranged, like cogs on a wheel, upon the margin of the orbules, while the remainder of the space is occupied by hornblende and large grains of black iron ore.

From a microscopical examination of thin sections, it is found that the component minerals of the orbicular facies are similar in appearance to those of the normal rock. The distinct character of the spheroidal structure is largely dependent

not only upon the disposition but the character of the hornblende. The core of an orbule contains a small amount of this mineral, which is more or less fibrous, being pale green in colour and accompanied by very little, if any, iron ore. A striking feature is that which may be referred to as the globular form of these hornblende crystals, the interior of which is less pleochroic than the surrounding fringe of smaragdite. In one orbule examined, the central part of these globular grains proved to be diallage (Plate XIV). In passing outward from the centre of a spheroid, the hornblende becomes more compact and darker in colour, being irregularly filled with inclusions of the titanifeous iron ore. In some orbules, this mineral is arranged both radially and in concentric zones, which are jagged in outline but possess more regularity than would be suspected from a microscopic examination. The farther from the centre, the darker is the colour of the hornblende and the more iron ore there is present until the fine-grained envelope is reached. In these envelopes the hornblende is very intimately intergrown with the plagioclase and is similar in character to that in the centre of the orbules. In the interorbicular spaces it becomes dark green in colour, having a much higher iron content, and is associated with numerous large grains of iron ore. Fibres of hornblende, either separately or in irregular bundles, penetrate the feldspar in every direction. Subsequent to consolidation, the rock has been traversed by small cracks, which are seldom more than two inches long and a millimetre in width. These cracks are filled with fibrous hornblende (Plate XIV). From its appearance some of the hornblende may have been a primary constituent of this rock, but undoubtedly the most of it is secondary, probably being formed by the alteration of diallage.

The core of each orbule is largely composed of basic plagioclase, the crystals of which are occasionally grouped in radial aggregates. This feldspar has the composition of bytownite ($Ab_1An_3$), although a few grains are present which have the indices of refraction corresponding to both anorthite ($Ab_1An_8$) and labradorite ($Ab_2An_3$). Toward the periphery of the orbules, the labradorite becomes the dominant variety. Twinning according to the albite and pericline laws is beautifully developed, and occasionally Carlsbad twinning may be

detected. In those zones where the hornblende is rich in iron, the feldspar is filled with fine inclusions of iron ore. Some of the crystals of feldspar show an incipient alteration to calcite. That the rock has experienced strain is evidenced by the undulatory extinction of some feldspar grains and the granulated borders of others.

In his comprehensive treatise on certain rocks which possess the orbicular structure, von Chroustschoff[1] shows that such spheroidal crystallizations may originate under very different conditions. They may be either primary structures, of the nature of segregations, which have developed during the crystallization of a homogeneous magma, or fragments of rock which, being enclosed by the magma, have been melted, re-crystallized and partially absorbed. Such inclusions may be detached fragments of the invaded rock, or products of an early crystallization of the magma itself.

Two explanations may be offered for the presence of the orbicular structure in the rock described in this paper. Either the spheroids were formed during the primary crystallization of the magma under the metastable conditions which existed at its contact with the invaded rocks, or they were produced by the partial re-fusion and re-crystallization of a marginal gabbroid facies of the granite. Although there are features of the occurrence which suggest the possibility of the latter method of origin, the writer is strongly inclined toward the belief that the former explanation is the correct one. In the growth of each orbule, crystallization of feldspar seems to have taken place almost to the complete exclusion of the ferromagnesian constituents, until through a fall of the temperature or an "increase in the gas content changed the saturation of the solution" with respect to the latter. Fluctuation in the temperature seems to have been an important factor, since in the concentric zones, and especially in the fine-grained peripheral zone, an eutectic point was reached at which both the feldspar and ferromagnesian minerals crystallized simultaneously. The changes in temperature may have been caused by the liberation of heat consequent upon rapid crystallization, which impeded further crystal growth "until diffusion of the heat permitted saturation to rise again."[2]

[1]Chroustschoff, K. von, Über Holocrystalline Makrovariolitische Gesteine. Mem. Acad. Imp. Sci. St. Petersburg, Vol. 43, Pt. 3 1894, pp. 1-245.
[2]Iddings, J. P.: Igneous Rocks, Vol. I p. 224

## Structural Relations.

These plutonic rocks are the crystallized equivalents of vast bodies of deep-seated magma called batholiths, which invaded the stratified rocks of the region. They were not formed during a single incursion of magma to a definite level; but, on the contrary, this igneous complex has been produced by repeated advances of the liquefied rock. In a few localities, the batholiths are partially separated from each other by partitions of the stratified rocks or their schistose equivalents. Occasionally one batholith is found to break across and send forth irregular apophyses into neighbouring batholiths.

Upon the western portions of the inter-fiord peninsulas, and on many of the islands, the intrusive bodies are smaller, and the contacts between them are more sharply defined than toward the interior of the Coast Range, where the fiords dissect the region to a much greater depth. The intricate relationship between the successive intrusions is displayed in an especially elaborate manner in such areas as Gilford, Midsummer and Canoe islands in Queen Charlotte sound; Reade, Cortez and the Redonda islands in the Gulf of Georgia, along the mainland from Powell river to Forbes bay, on the northern shore of Call creek, etc., etc. There are many localities where the roof has been little more than removed, the plutonic rocks exposed at the surface being laden with fragments of the stratified series as truly as when they are in lateral contact with a roof-remnant. In sailing up the larger fiords of the mainland, the magnificent sections afforded by their enclosing walls display progressively greater depths within the plutonic masses. Towards the heads of these fiords the mountains frequently rise from the shore to altitudes of from 6000 to over 8000 feet, and even the highest peaks have been profoundly unroofed, so that at sea-level the rocks exposed must have crystallized at a great depth within these former reservoirs of magma. Here the batholiths are very large and the boundaries between them are often vague; but even at these depths, there is no evidence of a floor, and the largest batholiths expand in width as their boundaries are traced downwards. These observations seem to constitute unequivocal proof that in those areas where the intrusive bodies are numer-

ous and small, erosion has not reached a sufficient depth to reveal the large plutonic masses from which the smaller ones emanate. It likewise seems probable that the batholiths emerged from a zone within the earth's crust where distinct boundaries cease to exist.

The close mineralogical relationship which these rocks bear to each other suggests that the different intrusive bodies were produced by the differentiation of a magma that must have been at least approximately of a homogeneous character. In general, the sequence of the intrusions has been marked by an increasing acidity of the magma with a corresponding decrease in its specific gravity. The hornblendites and some of the larger bodies of dark basic rocks are the oldest, while the light-coloured quartz-diorites, granodiorites, and granites are the youngest. As a rule differentiation has likewise taken place in the individual batholiths in such a manner as to form a peripheral zone of relatively basic rocks, such as dark diorites and gabbros, which shade gradually into an interior of more acid and homogeneous character. For example, near Kwalate point in Knight inlet, the hornblendites, which seem to be an ultra-basic marginal modification of the oldest batholiths within this area, pass gradually into a dark diorite. In some localities these basic modifications are wanting, and the batholiths are light in colour at their margins. For example, at Kelly point on Valdes island, granite is in immediate contact with massive volcanic rocks, and near Campbell point in Loughborough, the ferromagnesian minerals are almost entirely wanting where granite is in conjunction with limestone.

The stratigraphic record within this district is so destitute of fossils, and different groups of strata occupying different positions in the stratigraphic column are so similar and fragmental in their distribution, that without a more detailed study, it is impossible to assign a definite geological age to the successive intrusions. In fact, it does not seem improbable that they all belong to one programme of igneous activity, which was continuous in the region as a whole, but intermittent in a given locality, with intervals sufficiently long for successive cooling and solidification.

Since the batholiths intersect all of the stratified rocks, it

is certain that the last and greatest invasion of magma took place later than the Triassic, and possibly later than the early Jurassic. From analogy with the areas described by Daly and LeRoy, this widespread invasion of magma must have occurred at a time prior to the deposition of Cretaceous strata. The vast majority of these intrusive bodies may thus safely be regarded as of Jurassic age, probably being injected during the latter part of that geological period. It would seem that at that time this area was resting upon a deep-seated magma, which, by its intrusion in one locality and then in another, relieved the accumulating stresses. A number of batholiths of more basic magmas were the first to invade the region. They may be looked upon as the introduction to the chapter of igneous activity which followed. Although within a given locality periods of quiescence seem to have alternated with periods of renewed advance on the part of the magma, such periods of quiescence in one locality may have corresponded to periods of activity in another. The upward progress of some of the individual batholiths seems to have been of this periodic character. A single batholith must have advanced to a certain level and remained stationary for a sufficient length of time to permit the accumulation of more basic magma at its margins, and solidification through crystallization to a certain depth. Then followed a renewed demand for relief of stress in this immediate locality, the still molten and more acid magma of the interior ruptured the more basic and solidified peripheral portions of the batholiths and proceeded upward once more. For example, it seems difficult to otherwise explain how, in some localities, the granite batholith, which comprises the majority of the islands in Queen Charlotte sound, merges gradually with its basic marginal modifications, and in other places, the granite is in sharp contact with the same basic rocks. This intermittent intrusion of at least some of the batholiths will also explain the fact that in some cases the massive type of rock in the interior of such an intrusive body becomes gradually schistose toward the periphery, while, in others, the massive facies breaks across such schists and sends forth small dykes into them.

When in contact with the later intrusions the older plutonic rocks have been impregnated with disseminated grains of pyrite. For this reason some of these contacts are distinguish-

ed by an irregular rusty zone, which has been produced by the oxidation of the pyrite through weathering. Occasionally very small amounts of chalcopyrite accompanied the pyrite, and then the characteristic green colour, popularly known as "copper staining," appears upon weathered surfaces. These sulphides were deposited by the heated gases and vapours which were associated with the more recent invasion of magma. The presence of so much secondary hornblende in many of the more basic rocks, in which augite once seems to have been an abundant constituent, may also be explained as a result of the pneumatolytic and hydrothermal processes attending the intermittent or successive intrusion. That this uralitization has been produced by the bathing of these older rocks with the heated gases and vapours of later invading magmas, rather than by weathering, seems certain from a microscopical study of these rocks at different distances from their contacts with the more acid plutonic bodies.

The shape of the individual batholith is very irregular, but as a rule, its longest axis is approximately parallel to the structural trend of the region. Owing to this tendency on the part of the batholiths to assume elongated elliptical outlines, the type of plutonic rock changes more frequently when crossing the Coast Range than when a traverse is made parallel to its general N. W.-S. E. direction. In this respect, the form of each batholith is an expression of the persistency with which the stresses have come from the southwest, or northeast, and presumably from the former direction.

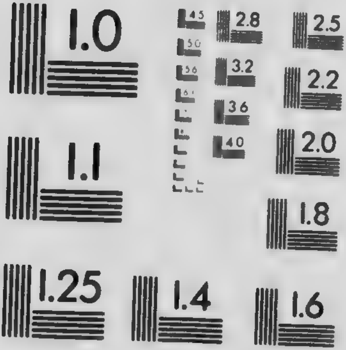
The large number of isolated areas of stratified rocks afford many opportunities for the examination of well-exposed contacts between them and the intrusive plutonic masses. The varying depths to which erosion has reached in carving out the trench-like fiords grants the more exceptional opportunity of examining "roof-pendants" of the stratified and schistose rocks as they descend to different levels in the batholiths. In each instance, the invading magma has rifted off a greater or smaller number of these rocks.[1]

Laboratory investigation is not necessary to demonstrate the absorption of these fragments. In many instances a complete sequence may be obtained in which, with increased dis-

[1]See description of same phenomenon by Dr. G. M. Dawson. Can. Geol. Surv. Report, Vol. II, 1886, p. 11B.

**MICROCOPY RESOLUTION TEST CHART**

(ANSI and ISO TEST CHART No. 2)



tance from an immediate contact, angular fragments, becoming more and more rounded, pass into weird forms drawn out with their longest axis in the direction of the magmatic advance, and finally, losing their individuality, appear as dark streaks or smears which, becoming in turn less and less distinct, are characterized by a higher percentage of ferromagnesian minerals. This sequence is especially well defined where the plutonic rocks are in contact with the schists. Here the rifting processes and their results are often displayed in a most spectacular manner, for the magma has so charged itself with blocks of schist that it is difficult to determine within a distance of a mile or so, where the boundary line between the two rock varieties should be located on the map, as near Alpha bluffs in Bute inlet.

The magma effected the separation of these blocks from the "roof-pendants" by the injection of a complex network of dykes. In some places its action seems to have been especially violent and aggressive, as at the remarkable contact between the massive volcanics of the Valdes formation, which is exposed on the northern shore of Johnstone strait, about five miles north of Port Neville. Here the magma ruptured the andesites into a vast assemblage of angular fragments of all sizes. In other places, the more liquid magma has advanced in a remarkably tranquil manner, injecting numerous dykes parallel to the planes of schistosity or stratification, so that mere parting layers or wedges of schist and argillites alternate with thin bands of the intrusive rock. Such dykes vary in width from small fractions of an inch to hundreds of feet. The wedges of schist may be a hundred feet or more in width with similar thicknesses of plutonic rocks intervening between them, as along the northern shore of Thompson sound; or they may have a width of an inch or less, alternating with dykes of the same order of magnitude, as in the patches of schistose argillites in Health bay on Gilford island, near Eden point on West Thurlow island, and at Fawn bluffs in Bute inlet. When small, these parallel injections usually possess a gneissoid structure, which has been induced by continued motion while in a viscous state. A specimen from such a dyke, two inches in width, which is interbanded with the argillites in Health bay, Gilford island, is gneissoid, with a tendency toward an augen structure. Under the microscope, in

thin section, this rock was found to have the composition of a quartz diorite, the component minerals of which show no evidence of dynamical metamorphism. Such dykes are not to be confounded with layers, retaining the original width and lamination of argillitic beds, which, when traced along their strike, have locally absorbed so much of the constituents of the magma that they have been altered to amphibolites, or biotite-hornblende gneisses.

In many localities denudation has extended to such depths that the tattered and frayed ends of the "roof-pendants" are exposed. In such instances, the stratified or schistose rocks are frequently traversed by an intricate network of irregular granitic dykes. In some of the areas designated upon the map as patches of stratified rocks, as on the eastern shore of McDonald bay, and at Adeane point on Knight inlet, huge fragments of crystalline limestones and schistose argillites really lie in a matrix of the invading plutonic rocks. Quite frequently, at a distance of several miles from any compact areas of schist, the plutonic rocks will assume a banded appearance, owing to the presence of layers of schist, from mere films up to a foot in thickness, which weather out upon the surface in parallel position. Typical occurrences of such banded structures are exhibited on the northern shore of Knight inlet, about a mile west of Lull bay, and on the eastern shore of Loughborough inlet, about three miles from Grismond point. In the former locality they extend for a distance of a mile or so along the shore, occasionally merging into a homogeneous diorite. The following diagrammatic sketch shows the relationship between the schistose bands and the grandiorite:—

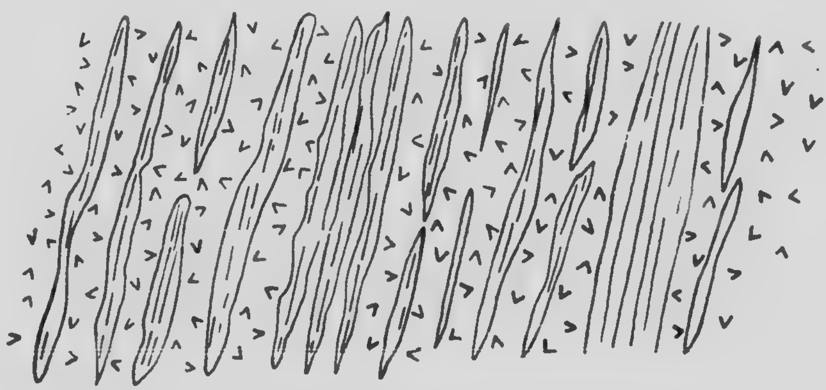


Fig. 5. Diagrammatic sketch showing the relationship between the schistose bands and the granodiorite.

Many of the bands of schist exhibit definite evidences of absorption by the magma, for their edges have a corroded appearance, and while of a dark grey colour at the centre, they shade into a light grey at the margin, where they blend with the interbanded granodiorite. The lighter colour is due to an enrichment of feldspar, anhedral crystals of which mineral, almost half an inch across, are sometimes developed in the outer portions of the schistose bands. The magma has been arrested, by cooling, in the very act of absorbing the schist by dissolving it.

The most remarkable feature in connexion with such parallel injections is that even the most isolated bands of schist have a similar strike, and where the connexion can be traced they retain the same strike as the compact parent masses from which they have been separated. Erosion in laying bare the lower limits of the roof-pendants has also demonstrated that, at least in many instances, these detached areas of stratified rocks are not true partitions between batholiths; but that the same body of the magma has welled up on either side of a pendant, reducing its width and length by the processes which have just been described. Nevertheless, such pendants have afforded cooling surfaces toward which differentiation has conducted the more basic portions of the magma.

Where the older dark-coloured plutonic rocks have been invaded by the batholiths of more acidic composition, the contacts between them are often marked by the presence of vast numbers of fragments of the former within the latter. Such a contact occurs on the northern shore of West Redonda island, at a short distance from Connis point. In some localities, as at Cascade point in Knight inlet, the newer magmas seem to have advanced before the older had consolidated, long dark streaks of a basic character, simulating the tails of comets in outline, appearing within the lighter rock.

PLATE XV.

(a) Folded argillites, Maurelle island, on Cardero channel.

(b) Inclusions in granodiorite near Styles point in Loughborough inlet.

In many localities, far from lateral contacts with the invaded rocks, the more recent batholiths are sprinkled through with a multitude of dark, rounded inclusions, the majority of which are less than a foot across. Frequently standing out in high relief upon weathered surfaces they differ from the including rock in that they contain less quartz, a higher percentage of ferromagnesian minerals, and their feldspars are usually of a more basic character. Some of these may be portions of the altered stratified series, but the great majority of them are presumably fragments of the older plutonic rocks, which have fallen from a roof shattered by the more recent advance of magma. That they are not basic segregations seems clear from analogy with the oft-repeated endomorphic contact phenomena already cited. This is further evidenced by the fact that some large blocks of dark plutonic rock, of varieties whose normal structural relations within the district have been determined, are occasionally surrounded by light granite or grandiorite in positions which must be at a considerable distance, either laterally or vertically, from the larger masses of which they were once a part. The inclusions may be seen in every stage of dissolution consequent upon their gradual assimilation by the magma.

The phenomena observed in the field corroborate the theory advanced by Daly concerning the processes by which the magma in a batholith gradually works its way upward. That the advance of the main portion of a batholith is preceded by or coincident with the intrusion of sheet-like apophyses, small stocks and dykes, which penetrate the fissures in the shattered roof, is well-exemplified in those portions of the region where erosion has not extended deeply into the plutonic masses. By means of these minor intrusions aided by stresses induced by unequal expansion and the movement of the magma, especially when plastic, at the immediate contact with the invaded rock, blocks of all sizes are rifted off from the roof. Upon being detached, these fragments of the roof are gradually melted and dissolved as they sink in the magma.

It seems highly probable that the stratified rocks of this region were folded either before or contemporaneously with the invasion of the batholiths. The magma ascended on either side of each limb of the folds, which were reduced in size by

the removal of fragments, as described, their remnants remaining as "roof-pendants." It likewise seems certain that those portions of the schistose roof-pendants which extended to the greatest depths in the magma, although not impregnated with typical contact minerals, were diminished by direct assimilation at their margins by the magma acting as a solvent. By these processes the magma enlarged its chambers for a period of time, which, in a given locality, depended upon its fluidity, the resistance offered to its advance by the roof, and the intermittent character of the stresses relieved by the intrusion.

Within this region, two main sets of joints traverse the rocks, one of which trends approximately N.W.-S.E., the other being at right angles to this direction. The jointing planes are either vertical or dip steeply to the eastward. On S. Valdes island, where they intersect the Valdes formation, the most pronounced set trends N. 20°-60° E. Among the plutonic rocks, they are often very wide apart, being few in number in some of the massifs, such as that of Granite mountain on Bute inlet.

That this region is traversed by faults, which assume the same general direction as the joints, is the belief of the author. It will require a more detailed study than was afforded by this reconnaissance survey to demonstrate the presence of a regional system of faults. Slickensiding and minor faulting are of common occurrence along the joint planes traversing the most massive members of the stratified series. That these rocks are intersected by faults with a very considerable throw is exhibited on Harbledown and South Valdes island. Baronet passage must follow the line of a fault with the downthrow side to the north. It seems certain that this faulting was caused by the differential adjustment of portions of the roof during the intrusion of the plutonic rocks. Where the stratified rocks are in thin beds which are much metamorphosed and steeply inclined, as they so frequently are in this area, it is almost impossible to determine the location of faults even if they do exist.

The occurrence of prominent roof-pendants on one side of a fiord and their absence or offsetting on the opposite shore, when considered in connexion with the straightness of some

of the fiords, such as Bute inlet, makes one very suspicious that a fault is present; but this cannot be regarded as definite proof of post-batholithic faulting, since the lack of continuity of the roof-pendants may be due to their having been cut off or broken across during the period of magmatic invasion. The Alexandria and Dorotha Morton mines on Phillips arm are situated on a fault which assumes a direction of N. 45–60 W., intersecting the biotite-muscovite granite of that district, probably extending southward along the channel which separates West Thurlow island from the mainland. Slickensiding was noticed on joint planes traversing plutonic rocks in several tunnels within the Phillips Arm district. The granite is locally sheared into sericite schists whose strike corresponds with this direction. The fine-grained siliceous rock of light grey colour, which was collected at the face of the Alexandria tunnel, proved upon examination in thin section under the microscope to be of the nature of a fault breccia, being composed of finely triturated plagioclase and orthoclase feldspars with much secondary quartz and a little muscovite. Dykes were noted to be faulted in a number of localities within the region, also showing that some displacement has taken place at a later date than the most recent intrusion of igneous rocks.

## Hypabyssal Rocks.

Dykes are so numerous that the total extent of their exposed surfaces constitutes a very striking and important feature of the bed-rock geology. They traverse all of the rock formations, and, although they belong to different periods of intrusion, the greater number of them must be regarded as the youngest rocks within the district. Their number is legion, it being unusual to make a traverse of a quarter of a mile without encountering one or many of them. Within the heart of the Coast Range (viz., toward the heads of the longest fiords), they are not so frequent in their occurrence as along its margin and upon the many islands. Although these dykes have a wide petrographical range, they may be divided into two main groups—the leucocratic or light-coloured aplites, pegmatites, syenite porphyrites, granophyres, etc., on the one hand, and the melanocratic or dark diorite porphyrites, diabase, malchites, etc., on the other. Certain porphyritic dykes of a com-

position which is intermediate between these groups are present, but they are few in number.

GROUP I.

Erosion has been carried to a sufficient depth in the fiords to demonstrate that the intrusion of the first group of dykes was directly associated with or closely followed that of the batholiths of granite and granodiorite. They are most extensively developed in those areas underlain by plutonic rocks or near their immediate contacts. They, however, do not appear within the central portions of the individual batholiths, but intersect their marginal parts—displaying the most clearly defined walls where they intersect the argillites, schists and the most basic of the plutonic rocks, such as the hornblendites, gabbros and diorites. Especially is this generalization true for the distribution of the aplites and pegmatites.

(1) *Aplites.* These dykes ordinarily vary in width from a fraction of an inch to five or six feet. In a few instances they are much wider, as on the southern side of Gilford island, where there are numerous irregular apophyses of aplitic granite, which have a breadth of several yards and from which true aplite dykes emanate. In certain localities, they are extremely irregular in width and direction and through repeated intersection form a complete network of dykes, as on the eastern side of East Thurlow island, just within the entrance of Malaspina inlet, in several prominent exposures on Bute inlet, etc. Their intersection is of so definite a character that one is led to the conclusion that there has been a series of intrusions of these dykes during different stages in the advance or cooling down of an individual batholith. Where the contact is exposed between the older hornblendites and gabbros and the granite, aplite dykes cut the former, but in tracing them into the granite they rapidly blend with it and lose their individuality. Some of the aplites branch, sending off irregular arms, which taper into stringlets that are highly quartzose in composition. At least some of the numerous quartz veins on the eastern side of Maurelle and East Thurlow island seem to bear a similarly close relationship of this nature to the aplite dykes that are present. In those areas underlain by hornblende schists, narrow tongues of aplite, often less than an inch in width, have sometimes been injected parallel to the

planes of schistosity. Apart from the areas where the aplites have been developed in groups, the more widely separated individual occurrences frequently possess a fairly persistent strike, which corresponds approximately to the trend of the Coast Range. Faulting of these dykes was occasionally noticed, as in Doctor bay on West Redonda island, where the throw has produced a horizontal displacement of ten feet in one of them.

The aplites are usually white, grey or slightly reddish in colour. They are very fine-grained, rarely possessing a texture which is coarser than that of loaf sugar. In a few cases their texture is the chief feature which distinguishes them from the granite itself, but, in general, they are composed of quartz and feldspar with minute flakes of biotite appearing as mere specks which are often widely separated. Orthoclase is a common constituent, but they are generally characterized by the presence of considerable plagioclase, which ranges from albite to oligoclase in composition. In a dyke near Salmon point on Bute inlet, the feldspar is oligoclase, and the flecks of biotite are arranged parallel to the walls, imparting a weakly gneissoid appearance to the rock, which must be considered as a primary feature in its crystallization. From the centre of another aplite dyke, near this locality, a perfect octahedron of magnetite was collected, which was slightly more than half an inch across. An aplite dyke near Brettell point, at the entrance of Toba inlet, has a blotched or mottled appearance, owing to the irregular development of secondary epidote.

(2) *Pegmatites.* Dykes of this type are not of frequent occurrence within this area, yet they are not uncommon. They are essentially composed of quartz, orthoclase, plagioclase biotite, and occasionally muscovite and magnetite are present. There is a striking absence of those minerals, such as tourmaline, fluorite, lithionite, etc., which are so often associated with pneumatolytic action. Plagioclase, in the form of albite or oligoclase, is often the dominant feldspar, and is sometimes present to the exclusion of the orthoclase. Graphic intergrowths of quartz and feldspar, and perthitic intergrowths of the feldspars are quite common. The pegmatites on the south side of Ramsay arm, about three miles from its en-

trance, consist of quartz, milk-white oligoclase, and crystals of a light brown biotite, some of which are two inches in length and an inch in width. A specimen was taken from a pegmatite dyke on the mainland opposite the southern end of Ragged islands, in which a reddish crystal of orthoclase about two inches long displays the graphic structure produced by intergrowth with quartz.

(3) *Granophyre.* With the exception of the aplites and pegmatites, there are very few dykes within this region in which quartz is visible to the naked eye. A dyke which cuts granodiorite at the head of Carrington harbour, on Cortez island, displays a few phenocrysts of greenish-black hornblende, some of which are an inch in length and a quarter of an inch in width, widely scattered through a grey, medium to fine-grained matrix composed chiefly of feldspar with a small amount of visible quartz, biotite, hornblende, and magnetite. Under the microscope the groundmass is seen to consist of numerous phenocrysts of plagioclase, which range from oligoclase to andesine ($Ab_4An_1$-$Ab_3An_2$), and a smaller number of quartz and orthoclase in a granular matrix, which possesses an almost universal micrographic structure produced by a remarkable threadlike intergrowth of the feldspars and quartz. The plagioclase is the predominant constituent, and in the lath-shaped phenocrysts frequently has a zonal structure, the centre of the crystal being andesine and the outer zone oligoclase. The biotite is occasionally intergrown with the hornblende, but it occurs chiefly in dense clusters of small crystals which have diverse orientation. A few needles of apatite, and small amounts of chlorite and epidote, formed from the decomposition of the biotite and plagioclase respectively, are present.

(4) *Syenite Porphyries.* The dykes to which this name is applied are so numerous that they constitute an important type. They are frequently cut across by the fine-grained dark dykes which are described under Group II. On the shore of Gilford island, opposite the eastern end of Kumlah island, an intersection of one of these syenite porphyries by a dark dyke may be easily seen.

Macroscopically, they exhibit abundant phenocrysts of feldspar in a light greenish-grey cryptocrystalline groundmass.

The phenocrysts have a more or less rounded appearance, and although seldom, if ever, more than one-fifth of an inch across, they are occasionally so numerous as to comprise fully one half of the rock.

A specimen from one of these dykes, which traverses granodiorite near the middle of the southern shore of Otter island in Desolation sound, was selected for microscopical examination. In the hand specimen forty phenocrysts of felds..., few of which exceed one-tenth of an inch across, appear ... a square inch of surface. In the thin section, it is found that the phenocrysts are oligoclase (Ab, An,), some of them being quite tu...d through incipient alteration to kaolin, and that the groundmass consists essentially of orthoclase, oligoclase, a small amount of biotite and hornblende with accessory quartz, both pyrogenetic and secondary epidote, orthite, a few grains of magnetite and long slender needles of apatite. A considerable part of the groundmass is characterized by a microspherulitic structure, in which the pseudospherulites consist of a crystographic intergrowth of feldspar and very subordinate amounts of quartz, biotite, and hornblende. The phenocrysts have frequently been the nuclei about which the radial growth took place. The pale green hornblende and the brown flakes of biotite are not abundant, occurring in the form of shreds, which are arranged in radiate or spray-like forms according to the shape which the spherulites assume. The spherulites have ill-defined boundaries, merging into the granular groundmass which exists between them. The orthite is sparingly present, being intergrown with the epidote, which occasionally is crystallized in the form of small fan- or sector-shaped aggregates.

(5) *Felsites.* These dykes are few in number, and were only noticed cutting granite rocks. They are grey to brown in colour, and so finely crystalline and dense in texture that their fracture is conchoidal. They are essentially composed of plagioclase feldspar, some crystals of which appear as microscopic phenocrysts in a groundmass in which the same mineral appears in the form of extremely fine grains of the same order of magnitude. A little magnetite, titanite, and secondary epidote are present in disseminated grains.

GROUP II.

Previous to the invasion of this region by the batholiths of the Upper Jurassic, the sedimentary rocks were traversed by a few dark dykes and intrusive sheets, which probably bear a genetic relationship to the extrusive andesites, dacites, etc., of the Valdes Series. Moreover, it seems probable that a few of the dykes were injected at the same time as those belonging to Group I.

Of more widespread distribution are the vast number of dark dykes, whose intrusion marked the close of igneous action within this region. From a comparison with the adjacent area to the south, it is evident that this last series was injected at some time during the period which elapsed between the invasion of the batholiths and the deposition of the Cretaceous coal measures. They cut the ore bodies of the district, and, although in a few instances they have a thin selvage of pyrite along their contacts, they have played a very subordinate part, if any, in mineralization.

From Adeane point to the head of Knight inlet, a distance of about 22 miles, very few dykes are present. In some localities, on the contrary, they have been developed in swarms, as on the northern shore of East Redonda island, Clipped point on Bute inlet, Henrietta point on Stuart island, the north shore of Arran rapids, the southern shore of Frederick arm, etc. On the northern shore of Pryce channel, and east of Double island, twenty-one of these dykes occur within a distance of one hundred yards.

They usually vary from one to ten feet in width, but occasionally attain to seventy feet or diminish to a few inches in breadth. They are frequently irregular in their strike, but the greater number of them either assume a direction which is parallel or transverse to the trend of the Coast Range, thus corresponding to the regional system of joints. Where the walls of the fiord are devoid of vegetation, these dykes often appear as dark, ribbon-like bands of a remarkably constant width, extending from the shore-line to the summit of mountains several thousand feet high. In general, the dykes are as durable as the rocks which they intersect; but many of the minor irregularities in the shore-line are due to the fact that

they have proved to be relatively more susceptible to the processes of erosion than the adjacent rock, while, on the other hand, when more resistant, they stand up as low walls. Respective examples of the forms produced by such differential erosion may be seen on the southern end of Harwood island and near Connis point on West Redonda island.

Generally their contacts are very sharp, but fragments of the wall rock are often scattered through their mass. This seems to be most commonly the case where the dykes traverse the limestones. In some instances a schistose structure has been developed within the dykes to quite a distance from their margins.

The dykes belonging to this group are lamprophyric in appearance, yet plagioclase enters into their composition to a greater extent than in those dykes to which Rosenbusch applies the term "lamprophyres." Their colour varies from a greyish-green to black. Macroscopically, those possessing a fine-grained to cryptocrystalline texture may be distinguished from those which exhibit a porphyritic structure. The uniformly fine-grained varieties are the most abundant.

The phenocrysts, which are seldom more than half an inch in length or breadth, are usually plagioclase, and less frequently orthoclase, greenish-black hornblende or augite. No specimens were examined in which the phenocrysts of orthoclase predominate over those of plagioclase. The plagioclase occurs in the form of rounded, prismoid or lath-shaped individuals, which are either irregularly scattered through the groundmass, or, as was noticed in exceptional cases, show a tendency to arrange themselves in stellar or irregular aggregates. Anhedral forms are more common than euhedral, and in general the porphyritic dykes may be said to have a seriate porphyritic fabric, since there is a wide range in the size and number of phenocrysts. By using the collection of oils of different indices of refraction, which have been prepared by Dr. F. E. Wright of the Geophysical Laboratory in Washington, D.C., for the purpose of determining the feldspars, it was found that, although the phenocrysts of plagioclase range in their composition from oligoclase ($Ab_3An_1$) to labradorite (Ab An), the majority of them are andesine ($Ab_3An_2$) of a slightly acidic character. In rare occurrences, hornblende is

present in the form of phenocrysts which assume the form of short but narrow prisms. Phenocrysts of augite are barely visible in a few of the dyke-rocks.

A microscopical study of thin sections demonstrates the fact that these dykes comprise a wide variety of closely related types. Diabase is the most common and widely distributed type; but, in addition, diorite porphyrites are present. A qualitative classification of these rocks is rendered more difficult by the uralitization of the augite, which causes the term *hornblende* diabase to become an appropriate one for describing the nature of some of these rocks. Uralitization has eliminated the augite from many of those diabases which cut the sedimentaries, and which are older than the plutonic rocks of the Coast Range.

The individual minerals correspond in their appearance, as a rule, to those varieties of the same minerals which occur in the plutonic rocks of the region. Biotite is of very rare occurrence in these dykes, and, when present, occupies a less important position than the hornblende which accompanies it. In some cases the biotite is intergrown with the hornblende. The augite is colourless or pale yellow in thin section, and shows every stage in the process of uralitization. Hydrothermal action seems to have been responsible for the alteration of the augite to uralite. Frequently the phenocrysts of augite have a corroded appearance, the embayments being filled and the crystals surrounded by uralite and magnetite which have been formed together. It seems probable in some cases that the augite has been changed to the more stable hornblende at a period previous to the final consolidation of the rock. The primary hornblende belongs, in general, either to the common or basaltic varieties, and when in phenocrysts this mineral often displays twinning.

Plagioclase is the dominant feldspar, the orthoclase being present in relatively small amounts or is entirely absent. The plagioclase usually occurs in the form of long narrow lath-shaped individuals, which are remarkable for their twinning and for the zonal structure, which is often developed not only in the phenocrysts, but also in the smaller individuals, which usually form a high percentage of the uniformly fine-grained rocks and of the groundmass of the porphyrites. In the por-

phyritic dykes, it is clear that, in some cases, different generations of feldspars have been formed, since the phenocrysts have been broken and the cracks are filled with the assemblage of minerals of which the groundmass is composed. Quartz seems to be always present in small quantities. Magnetite, titanite, and needles of apatite are widely disseminated accessory constituents.

Secondary minerals are numerous and often comprise a large percentage of the minerals present. The widespread occurrence of epidote and chlorite, separately or together, explains the various shades of green which characterize the hand specimens. Epidote and zoisite are secondary after the feldspars and augite, the former mineral occasionally forming pseudomorphs after the phenocrysts of plagioclase. Chlorite has been produced through the alteration of the hornblende and augite. Calcite, secondary quartz, and leucoxene are never so abundant as the epidote and chlorite, but they are of frequent occurrence.

## Quaternary Deposit.

### PLEISTOCENE.

The oceanic waters of the continental shelf must conceal by far the larger part of the debris formed during the glacial denudation of this district. While some of the detritus was irregularly deposited on the bottom of the fiords, or contributed to the fishing banks of the Gulf of Georgia and Queen Charlotte sound, a considerable portion of it was probably consigned to greater depths, being distributed over a much wider area of the oceanic floor through the medium of icebergs as transporting agents.

The glacial deposits which occur above sea-level constitute only a very small fraction of the products of such erosion. Although superficial deposits are absent over wide areas, glacial drift is very irregularly deposited over portions of the surface of the forelands, and of the least mountainous portions of the rocky islands; but the most extensive deposits are those which comprise the islands of Harwood, Savary, Hernando, Mary, and the southern extremities of Cortez and South Valdes islands. These islands are situated in the northern part of the Gulf of Georgia, being arranged along a line which has a

direction of about N. 70 W. They are composed chiefly of horizontally stratified sands, which vary in colour from yellow to grey and white.

In some places the shores rise as cliffs from the sandy beach; in others the ascent is very gradual. The frequent occurrence of false-bedding, the variation in the size of grain in successive layers, and the pebbles which are deposited among some of the finest silts, show that they were deposited by currents which fluctuated in strength and direction. On the northern shore of Savary island, near the eastern end, a persistent layer of fine-grained black sands (magnetite) occurs, which is 3 to 4 inches in thickness. In the cliffs on the southern side of both Harwood and Savary islands, large irregular bodies of boulder clay are exposed, which rest in hollows upon the more fine-grained stratified silts, and in the latter locality are covered by much coarser sands and gravels. The huge boulders which are scattered along the shores, or are congregated to form the reefs which extend southward from Cape Mudge, Mary island, Reef point, and Hernando island, suggest the presence of a lower boulder clay from which the larger number of these rocks has been washed by the sea. On the north side of Savary island, about two miles from its eastern extremity, boulder clay occurs at a much lower level than on the opposite side of the island. Since it is covered by the finer silts, it must be older, but the sand which had fallen down so masked its downward extension that it was impossible at that point to determine whether it constitutes a portion of a widespread basal deposit or not.

Because the boulder clay is more impermeable than the overlying sands, water finds its way along its surface to the face of its slope either as seepage or, as was noticed in one instance, in sufficient volume to form springs. That these unconsolidated sediments and boulder clays rest upon glaciated bed-rock surfaces was demonstrated from observations on S. Valdes, Cortez, the northeast corner of Hernando, and the eastern end of Savary islands. The soundings recorded on the chart show that the water between Harwood, Savary, and Hernando islands is shallow, while depths of at least 300 feet exist in the channels between Cape Mudge, Mary island, Reef point, and Hernando island.

It is highly probable that the line along which these islands are distributed represents either the position at which the margin of the Gulf of Georgia glacier tarried for a sufficient length of time, during its retreat, to build a terminal moraine, or the position of four medial moraines which were formed between glacial tongues which occupied the deeper channels.

During the latter part of the Glacial period, the land was at least 350 feet lower than at present, as is shown by the terraces which occur at this altitude, at the mouth of Powell river, on Desolation sound, and on Texada island. Subsequent to the deposition of the boulder clay, sediment charged waters laid down the stratified silts. A second advance of the glacier, which was by no means so vigorous as the first, furrowed these sediments, and its recession left behind what is probably a *second* boulder clay, which, in turn, was covered by the coarser sands and gravels. Some of the more striking irregularities in the bedding of the latter may be explained by the melting of entangled ice blocks.

Unmodified drift occurs in remarkably few and widely separated localities within this region. Eastward from Granite bay on Valdes island boulder clay is very irregularly strewn over the surface, and near the bay it is covered by stratified sands and gravels. Deposits of till, which were comparatively free from boulders, were noticed in Bear bay on Bute inlet, in Glacier bay on Knight inlet, in the vicinity of Roy P. O. on Loughborough inlet, and Bold point on the east side of S. Valdes island. Erratics are scattered upon low summits and slopes of easy gradient. They occur in such numbers at the head of Ramsay arm, near Hoeya sound on Knight inlet, and along the southern portion of Chatham channel, as to warrant the mention of these localities.

Along this coast, terraces are few in number and limited in area; but they are of about as frequent occurrence as modern sandy beach deposits within the same area. Their position suggests that they were formed as pocket beaches, or deposited upon the surface of the lowest foreland areas, at a time when the land stood at a lower level than at present. It is highly probable that some of them are kame terraces which have been worked over by the waves. Within Bute and Knight inlets their presence was not noted, and it seems

probable that glaciers persisted within the larger mainland fiords during the time that terraces were being formed along exposed shores. They most frequently occur at altitudes of from about forty to seventy-five feet above sea level. Remnants of such terraces, composed of sands and gravels, are prominently situated in the following localities:—on the southern side of the entrance of Theodosia arm, southward from Squirrel cove on Cortez island, from Read bay to Hansem point within Topaze harbour, in the vicinity of Port Neville and Blinkinsop bay, southeastern shore of Hardwicke island, on eastern end of W. Thurlow island near Green rapids, and in the vicinity of Sidney bay and Beaver creek within Loughborough inlet.

Deposits of stratified clays were observed at the head of several small bays, or in the beds of streams. In general, they are characterized by a bluish colour, compact texture and a tenacious habit when wet. When dry, they may be readily crushed into a powder which is slightly gritty or impalpable. Occurrences of these clays which were noted are situated near the shores of some of the bays on Reade island, in the beds of a stream which enters Open bay on S. Valdes island, on the south side of Maurelle island, about a mile and a half from Surge narrows, in the bed of a stream just west of Roy P. O., on Loughborough inlet, and in a cove on the south shore of the harbour of Port Elizabeth on Gilford island.

The above mentioned occurrence of clay on Maurelle Island is capped in some places by a few feet of sand which occupy a position about twenty feet above sea level. The transition beds are of a buff shade and quite shaly in nature. The clay itself contains a considerable percentage of sand, the microscope revealing the presence of small fresh grains of quartz, feldspar, and hornblende distributed through a base of kaolin.

The only locality where marine shells were seen among the unconsolidated sediments had been previously discovered by Mr. J. Cameron of Granite Point camp, where the clay is exposed in the bed of a stream which enters Open bay on S. Valdes island. While making a traverse in the interior of this island, this stream was crossed at an estimated distance of a mile from its mouth where the shells occur. They usually occupy life-like positions, many of the valves not being separated and only partially filled with clay, which is occasionally

dark in colour because of the decay of the soft parts. Specimens were collected of Cardium Islandicum, Leda pertunda (var. buccata), Nucula, and a fragment of a Mactral (?). The brown cuticle still adheres to the surface of the Leda, one of the shells of which was bored through, presumably by a sponge, since broken spicules of a sponge were demonstrated to be present by a microscopic examination of the clay. Under the microscope the clay is seen to contain a considerable number of tests of Diatoms.

*Modern.* Since the amelioration of the climate, which attended the recession of the ice, the accumulation of delta alluvial, and beach deposits has taken place, together with the formation of a considerable thickness of vegetable mould in favourable localities.

## ECONOMIC GEOLOGY

### General Statement.

Although a considerable amount of work was being conducted upon certain mineral claims within this region during the period at which this geological investigation was in progress, none were developed to such a stage that regular shipments of ore were being made from them. The gold mines in the vicinity of Shoal bay, Phillips arm, and Frederick arm had been shut down for a number of years, and very many of them were filled with water, or were in such a dilapidated condition that it was impossible to examine them.

Effective prospecting is attended with many difficulties owing to the rugged character of the topography, and the dense vegetation which clothes the slopes. The disconnected areas which are underlain by stratified rocks are worthy of very careful attention while prospecting, for it is these rocks which carry the ore deposits. The character and amount of mineralization depend very largely upon the nature of the stratified rocks which contain them. In general, the ores found within this region are either magnetite or the sulphides of copper and iron, which sometimes carry small amounts of gold and silver. Heated waters and vapours emanating from the vast batholiths of the Coast Range have been the chief source of mineralization. Within those areas where the volcanic rocks of the Valdes formation are exposed, certain de-

posits of copper ore seem to have been formed by the concentration of sulphides of this metal which originally existed locally within fresher portions of the rocks as widely disseminated particles of minute size. The multitude of dykes which traverse all other rocks within the district bear no relation to the deposition of economic minerals.

COPPER DEPOSITS IN THE VALDES FORMATION.

The deposits of copper ore which are associated with the volcanic rocks of the Valdes formation occur chiefly in the form of chalcocite, chalcopyrite, bornite, and native copper. Within this region chalcocite was only noticed to be present in this Valdes formation. In addition to these minerals, which have been mentioned in the apparent order of their abundance, malachite, azurite, and the black and red oxides of copper are occasionally present in small quantities near the surface of the deposits. These ores occur along joint planes and sheer zones, often irregularly impregnating the rock on either side; in veins and veinlets associated with calcite, quartz and epidote; or as grains disseminated throughout the more amygdaloidal and highly epidotized and chloritized portions of the basalt. Occasionally, while walking over the surface of such an altered amygdaloidal bed, irregular patches may be met with which are characterized by the presence of small quantities of native copper or chalcocite, or both, which seem to bear no connexion to existing fissures. Calcite, quartz, epidote, and prehnite are often associated with these copper minerals in filling the amygdules.

Two theories may be advanced to explain the origin of these ores. First, that the copper bearing solutions emanating from the batholiths of the Coast Range, while they were cooling down, ascended along certain shear zones and joint planes in the Valdes formation, impregnating the adjacent rock with the sulphides of copper, especially along those horizons where the beds are highly amygdaloidal. Second, that these deposits were formed by the concentration in favourable localities of copper-bearing portions of the volcanic rocks, the copper in which originally existed as minute particles of some copper sulphide, probably chalcopyrite. Sufficient development work has not been done to indisputably determine

as to which theory is correct, but because of the manner of occurrence and the character of the mineralization in at least the majority of cases, the writer is inclined strongly in favour of the second theory. It is a well-recognized fact that such volcanic rocks frequently contain small amounts of copper. In those localities where downward percolating waters have enjoyed an easy passage, as along shear zones or where joint planes are close together, or in the more amygdaloidal horizons, these waters have not only largely altered the original minerals of the igneous rock to such secondary minerals as epidote, calcite, quartz, and zeolites, but have concentrated the original small copper content.

It is, however, not beyond expectation that within the neighborhood of contacts between the volcanics and the intrusive batholiths, or along pronounced shear zones in the former rocks, mineralization took place as outlined by the first theory.

## SOUTH VALDES ISLAND.

That portion of South Valdes island which lies between lines extending across from Kelly point, and Quathiasca cove on the west, to the southern shores of Open bay and Drew harbour, on the east, is underlain by a typical development of the Valdes formation. In the southwestern part of this area, in the vicinity of Copper cliffs, Gowlard harbour and Quathiasca cove, some of the beds of basalt and augite-andesite are very amygdaloidal and, locally, are mineralized in the manner outlined in the immediately preceding paragraphs. The volcanic rocks within this area are traversed by joint planes, the most prominent and persistent of which run almost due east and west, along many of which movement has taken place, as is evidenced by the frequent presence of slickensided surfaces. There seems to be no evidence of faulting with throws of more than a few feet. The distance between these joints, and the variable amygdaloidal character of the beds, have largely controlled the extent of the mineralization. It will be surprising if within this area, some of these small deposits of copper sulphides, chiefly chalcocite, do not prove to be valuable low-grade copper propositions. The following description of mineral properties within

this area will serve to illustrate the character of these deposits in detail.

The *Copper Cliff* mine is situated on the face of Copper cliffs, which rise steeply from the waters of Discovery passage on the west side of this island. Here and there the cliffs are stained with the green carbonate of copper, malachite, and upon closer examination the volcanic rocks are found to be impregnated in a very irregular manner with small grains of chalcocite which usually occur within the amygdules, and to a much less degree in the solid portions of the altered rock. In so far as could be determined, the strike of the beds in this locality is N. 40° W., with a dip of 30° to the southwest. Along some of the joints the rock contains many of the small brilliant grains of chalcocite which become less numerous at a greater distance away from the planes of fracture, until the interior portions of the larger joint blocks are barren. A tunnel, running S. 60° W., had been driven into the cliff for a distance of about 100 feet, along a very amygdaloidal horizon in a thick bed of augite-andesite. The face of the tunnel displayed a number of slipping planes, quite close together, with particles of chalcocite distributed through a zone in the rock, which was seven feet wide. The mouth of the tunnel is at such a level above the sea that the ore may be readily loaded into vessels from a bunker which holds 150 tons. Two small shipments of hand picked ore had been sent to the Tyee smelter.

The *Commodore* group embraces five claims which are situated to the north and east of those included within the property of Copper Cliffs. Here certain beds and horizons of very irregular thickness within the lava flows of the Valdes formation are also amygdaloidal.

In so far as distribution is concerned, the mineralization bears a similar relationship to the amygdaloidal beds and to an east-to-west set of joint planes, along some of which movement has taken place, as it does on the property just previously described, but in this case, in addition to chalcocite, chalcopyrite, bornite, and native copper were locally present. As in the case of the Copper Cliffs property, the mineralization has been widely distributed, but sufficient work had not been done to demonstrate that these low-grade ores can be mined profitably on a large scale. The chief difficulty to be encountered is the irregular character of the mineralization.

At a point where a shaft had been sunk to a depth of twenty feet, grains of chalcocite were found to give way to those of chalcopyrite, at a depth of about seven feet. Two small open cuts, and two tunnels, thirty and thirty-eight feet long, had been made at different points where surface indications seemed to offer the best promise. The longer tunnel was driven into the face of a cliff [illegible]re the amygdaloidal rock was more or less impregnated with chalcocite, for a maximum width of forty feet.

On the southern end of *Steep island* in Gowland harbour, a certain amount of trenching and open cutting had been done [illegible] a thick amygdaloidal bed, which is traversed by many joints, some of which are in reality minor faults. Mineralization seemed to be fairly uniform in character, and about sixty tons of ore were on the dump ready for shipment.

On *Gowland island* a property was visited upon which a tunnel had been driven for 120 feet, within which a shaft 20 feet deep and a raise of 15 feet, had been made. The workings followed a zone along which the volcanics are sheared into a chlorite schist which contains a few scattered grains of chalcocite.

The *Carl Goody* claim in Gowland harbour, but on S. Valdes island, was also visited. A shear zone, along which chalcocite occurs within the amygdules of the adjacent rock, had been exposed but sufficient work had not been done to show the amount of the impregnation.

The *Ingersoll* mineral claim is situated on the southern slope of a hill at a distance of about one mile and a half north of east from Copper Cliffs. The volcanics are traversed by a fault zone which, striking almost due east and west, apparently has a downthrow towards the south. Along this zone which had been stripped for a distance of 375 feet, the adjacent rock is very irregularly impregnated with chalcocite, which through weathering at the surface has given rise to traces of malachite, and the red and black oxides of copper. The position of the fault-zone is marked by slickensided surfaces and by gash veins of calcite and quartz which locally contain chalcocite. On either side of the narrow zone so characterized the rock is irregularly impregnated with small par-

ticles of chalcocite for a maximum width of 34 feet. At that point, where a shaft had been sunk to a depth of 16 feet, the mineralized zone is reported to have been found of less width than at the surface. A trench, 80 feet long, had been driven into the side of the hill, and this upon reaching the fault zone likewise demonstrated the decrease in width of the mineralized zone at about the same depth. Mr. W. T. Sauls, who owns the property, informed me that a nugget of native copper weighing 108 lbs. had been taken from the shaft, and that an assay of a picked specimen of the vein material showed the presence of 8 per cent of copper and traces of gold and silver.

The *Dominion* and *Wide Awake* mineral claims, situated to the northeast of the Ingersoll and about 1500 feet from the boundary line of the latter, showed exposures of the greenstones, within the amygdules of which were scattered grains of chalcocite, azurite, and malachite.

On the *Skookum Chuck* mineral claim, opposite Seymour narrows, two shafts, 9 and 20 feet deep respectively, have been sunk in the amygdaloidal greenstones. A few specks of chalcocite and chalcopyrite were noticed in samples lying about the mouths of the shafts which contained water.

The *Hugo* claim, just south of Seymour narrows, has been staked because of the presence of an irregular vein of quartz which has a maximum width of six inches. The quartz is arranged in radiating crystal aggregates, between the crystals of which are small grains of chalcocite and bornite.

On the northwestern corner of Heriot island, in the bay of the same name, on the eastern side of S. Valdes island, small particles of native copper were noticed to be present in amygdaloidal greenstone, the amygdules of which were otherwise filled with calcite, quartz and epidote.

The *Ajax* mineral claim is situated a little more than a mile inland from the northern slope of Deep Water bay, on the west side of South Valdes island, at an altitude of about 900 feet. The main tunnel follows a shear zone running N. 75°-80° E., which is traversed by irregular veinlets of chalcocite in a gangue of calcite and a little quartz. The rock in the immediate neighborhood of these small veins likewise carries a few scattered grains of chalcocite. At the time of examina-

tion the face of the tunnel displayed an almost vertical fault plane, the position of which was distinctly marked by a narrow seam of dark tenacious clay gouge, on either side of which the rock held a few particles of chalcocite. Samples selected from the dump showed that some of the veinlets encountered while following this zone must have had a width of from six to eight inches. A cross-cut was being driven to intersect a parallel zone of shearing which appeared at the surface as a band of chlorite schist traversing the volcanic rocks, and locally impregnated with small grains of chalcocite.

### CRACROFT ISLAND.

In Boat harbour, on the southern shore of this island, a tunnel has been driven, to intersect a shear zone in the volcanics, which apparently runs N. 30° W.; and along which the rock upon the surface of the cliff is impregnated with chalcopyrite for a maximum width of about 18 inches. Small pieces of solid chalcopyrite can be removed by hammering. Upon the surface the blue sulphate of copper appears as a thin, irregular encrustation. The tunnel does not seem to have met with this zone before being abandoned. This mineral claim is called the *Copper Queen*.

In the vicinity of the eastern entrance of Baronet passage the amygdaloidal greenstones, on the northern shore of this island, were noticed to contain a few specks of bornite, pyrite, and native copper within the amygdules.

On the western shore of a small bay, about two miles westward from the last mentioned locality, a shaft 10 feet deep has been sunk in the volcanic greenstones where they are traversed by stringers of quartz and chert carrying a very little chalcopyrite, bornite, and azurite. These minerals are, to a limited extent, diffused through the much decomposed amygdaloidal rocks.

### HANSON ISLAND.

Along the southeastern shore of this island, the volcanic greenstones of the Valdes formation have been very much altered. Epidote and quartz, both of which frequently occur in the form of knots or bunches of radiating crystals, are abundant, together with calcite, chlorite, and zeolites. A

few small grains of bornite and native copper were noticed within the more amygdaloidal and weathered portions of the rock, at a point about two hundred yards east of the entrance of the tunnel of the *Hanson Island* mine. This tunnel was driven along a shattered zone in the greenstones for a distance of 165 yards, in an almost due north and south direction. Where this zone is exposed along the shore at low tide the rock is locally impregnated with chalcopyrite for a width of four feet. At an altitude of about 125 feet above sea-level, a well-constructed shaft has been sunk, apparently to connect with the tunnel. In the tunnel only a few specks of chalcopyrite were noticed in the sheared portions of the rock, but good samples of solid chalcopyrite were lying on the surface about the mouth of the shaft.

## Mineralization Within the Contact Aureoles of the Batholiths.

Few of the areas of stratified rocks are of such extent that they have not to a greater or less degree suffered the effects of metamorphism induced by the heated waters and gases whose escape attended the intrusion of the batholiths. Mineralization has been restricted almost entirely to the roof-pendants of altered stratified rocks; much less frequently the ore bodies are enclosed in the immediately adjacent plutonic rocks, the peripheral portions of the batholiths apparently in some cases having been bathed by mineralizing solutions emanating from the cooling interior parts.

Many of the ore deposits occur along contacts between the plutonic and stratified rocks, replacing the latter, and being associated with such minerals as epidote, wollastonite, garnet, vesuvianite, etc. Limestone is especially susceptible to such replacement. The magnetite on the north shore of W[illegible] [illegible] and is an excellent example of such a contact deposit. Or, the deposits are situated at some distance from the immediate contact where ascending mineralizing solutions have found an easy passage, as along lines of fissures, shear zones, or where bedding planes are close together. The shear zones and fissuring may have originated from the adjustment of the stratified roof and peripheral portions of the batholiths during the shrinkage consequent upon the crystallization of the molten magma beneath. In some cases chalcopyrite, pyrrhotite, pyrite, and magnetite have been deposited along

the same line of weakness, as on the Lucky Jim claim in the mineralized area to the southeast of Granite Point camp on South Valdes (Quadra) island.

On account of the small amount of development work which has been done within the region, it is impossible to formulate a general rule concerning the persistence of these deposits. It would seem that owing to the very irregular character of the mineralization, too much stress should not be laid upon surface showings without further development.

The following detailed description of mineral properties will serve to illustrate the character of the mineralization which seems to have been produced in the manner just outlined:—

WEST REDONDA ISLAND.

The *Redonda iron mine* is situated on the northern shore of this island, at a point which is about S. 35 W. from Hepburn point and S. 11° W. from Elizabeth island in Pryce channel. It was staked as "the Elsie mineral claim in 1892 and Crown-granted to De Wolf and Munroe of Vancouver in 1895."[1]

The north shore of West Redonda island rises very steeply from the sea to a height of over 3000 feet. The rocks exposed along this bold shore line comprise a porphyritic granodiorite which shades off into a light grey hornblende granite, both of which include patches of massive darker rocks which are very rich in hornblende and which undoubtedly represent highly-altered portions of the roof beneath which these batholiths cooled. Upon the shore line of this property there is a patch of dark rock extending for a distance of about 120 feet which contains a few fragments of altered crystalline limestone.

Where this property is situated, the water is very deep at the shore, and the ascent to where the ore outcrops, at an altitude of about 450 feet, is a difficult one. At this altitude the slope becomes more gentle up to about 600 feet, owing to the presence of a much altered crystalline limestone which occupies the position of a roof-remnant or curtain with reference to the surrounding plutonic rock. The main mass of the ore as exposed, is situated at the well-defined contact between the altered limestone and a light grey hornblende granite. The

[1]Report of the Minister of Mines in British Columbia, 1901, p. 1113.

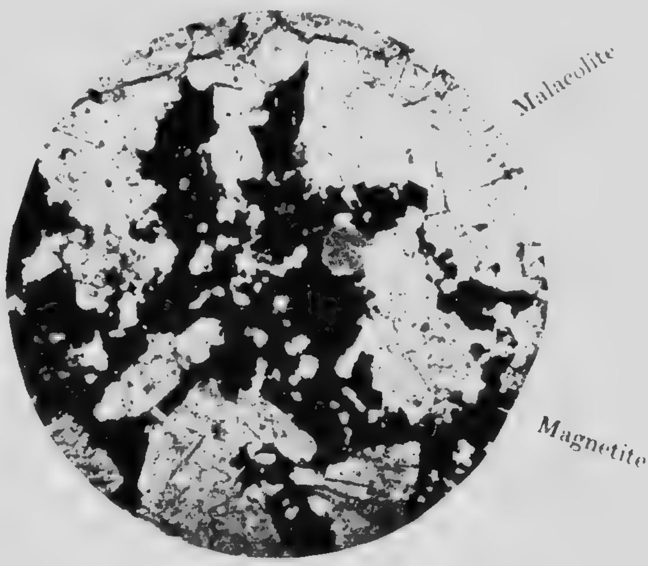
ore body is a typical contact deposit which has been formed by heated solutions which, emanating from the plutonic magma, while cooling, altered the limestone to its present condition. An open cut has been made which is 54 feet long and extends into the body of magnetite for a distance of about 20 feet. In part the ore is solid magnetite, but in general the magnetite occurs in nests, granules, or reticulating veins through the limestone, which has been almost completely altered to a pale green pyroxene, probably malacolite. Smaller amounts of quartz, epidote, chlorite, and calcite are also present in much of the ore, and in thin sections under the microscope the presence of a few granules of sphene is revealed. The pyroxene is usually of a fine, granular nature, but occasionally becomes quite massive, or, by twinning, has been arranged in radiating aggregates with fibres up to two inches in length. Some of the pyroxene has been altered to bastite, which change is rarely visible in hand specimens, but in thin sections is displayed in every stage of its development. In general, the magnetite seems to have crystallized somewhat later than the pyroxene. (See Plate XVI.) Irregularly distributed throughout the solid ore are a few small cavities in which the magnetite has assumed the form of small crystals, up to a half inch across, some of which are remarkably perfect in their development. The most common crystal form is the rhombic dodecahedron, less frequently a combination of the dodecahedron and octahedron. The following is an analysis of some of these crystals, which was made by Mr. A. O. Hayes, M.Sc., while a senior student in chemistry at McGill University:—

$Fe_3O_4$—69·34%; $Fe_2O_3$—29·33%; $SiO_2$—0·89%.

A much dilapidated chute extends to the beach, the descent of the ore along which was arrested by two bunkers, constructed at different altitudes. In 1893, 626 tons of ore were taken out and shipped to the Oswego Iron and Steel Company's furnace in Oregon. Since then, a smaller shipment is reported to have been made. Because of the small amount of work done upon this property it is impossible to make a statement concerning the quantity of ore. The ore is excellent in quality and in distribution occupies a larger area than that which as yet has been exposed to view. About fifty yards eastward

PLATE XVI.


(a) Photograph of thin section of iron ore, from Elsie mineral claim, West Redonda island. Magnified 3 diameters.




(b) Iron ore from Elsie mineral claim, West Redonda island. This microphotograph was taken at point A in above thin section.

from the open cut, the writer removed some of the thick blanket of moss which covers the hillside, and found magnetite which apparently had never been uncovered previously. The depth to which the ore body and altered limestone descend into the granite might easily be determined by drilling.

SOUTH VALDES ISLAND

Along a belt extending from Open bay on the east, toward Granite Point camp, a series of stratified rocks outcrop, which pass beneath the massive Valdes formation toward the southwest, and are cut off towards the north and east by the irregular intrusive contact of the Coast Range batholiths. These rocks include quartzites, typical argillites in ribboned layers, up to six inches in width and intercalated sheets of dark volcanic rocks, some of which are porphyritic and some similar to the more massive portions of the Valdes formation. Some of these sheets are distinctly intrusive, others may be extrusive. At the base of the series, massive limestone layers predominate, these being regarded by the writer as belonging to the Marble Bay formation. The whole series is traversed by dark dykes which seem to fall into two distinct sets; an older antedating the intrusion of the batholiths and probably related to the period of intense volcanic activity during which the Valdes formation was formed, and a younger, belonging to that group which are younger than any other rocks in the region. The strike of the series varies locally but in general is N.W.-S.E., and most frequently N. 45° W. to N. 60° W. The dip also varies, generally approaching the vertical. That the region is traversed by faults is very evident, along certain zones some of the rocks being sheared into schists, while along many of the joint planes slickensiding is displayed.

This area was not visited until the close of the season's work, and it was possible to spend only portions of two days upon it. The geological boundaries represented upon the map have no claim for accuracy but are delineated to emphasize the presence of a belt of country which is worthy of the most careful prospecting, while certain properties already known should be more thoroughly tested by more development work. The region is easily accessible from Granite Point camp, from which a short railway, about four miles in length, has been built to bring logs to tide water. The fol-

lowing description of a few properties examined will illustrate the general character of the mineralization.

Upon the *Geiler* two shafts had been sunk to depths of 20 and 14 feet respectively, and some trenching had been done. The first shaft is situated near a contact between limestone and highly altered argillaceous rocks. The second is in a shattered zone between two dykes, which apparently belong to the older series, since mineralization has been of later occurrence than the dykes themselves. Pyrite, pyrrhotite and chalcopyrite are present, either in the form of disseminated grains in the country rock or in irregular bodies of very small size composed of almost solid ore. One of the trenches has exposed chlorite schist, representing metamorphosed intrusives or extrusives, which is impregnated with pyrite and chalcopyrite. Mr. J. Cameron, the owner of the property, informed me that the assay of a picked sample showed the presence of 18 per cent copper, $3.72 in silver and $5.60 in gold. One of the specimens from Shaft No. 1 displayed a small particle of free gold.

Upon the *White Swan* there is a small exposure of altered limestone, striking S. 40° E. and dipping at an angle of 25°, containing small amounts of chalcopyrite and pyrite. A specimen selected from the surface is reported to have assayed $17.60 per ton in copper with a little gold.

On the *Triangle* a few grains of chalcopyrite, galena, arsenopyrite, and pyrite are scattered along a narrow zone of shearing where it traverses crystalline limestone. The presence of small black, needle-like crystals of tourmaline, which were arranged in sheaf-like aggregates upon the surface of a joint plane in this limestone, is corroborative evidence for the belief that the origin of these ores has been closely associated with the pneumatolytic action attending the cooling down of the batholiths.

The *Lucky Jim* mineral claim shows greater mineralization than any of the other claims which were visited. Along a narrow zone running N. 15° W., irregular lenticular bodies of limestone occur at intervals, intercalated between rocks of the volcanic series. Within a distance of 340 feet along this zone there were two small open cuts and a shaft 12 feet deep

had been sunk and a considerable amount of trenching had been done. The most northerly open cut displayed limestone containing a relatively small number of disseminated grains of chalcopyrite and pyrite. The next open cut, 100 feet removed, showed a mass of pyrrhotite containing a little chalcopyrite and pyrite, with a maxium width of 17 inches, lying between the volcanics. A little farther southward is an exposure of the same minerals associated with quartz and having a maximum width of 4 feet. Forty feet from this point, 10 feet in thickness of limestone is exposed, on one side of which there is a narrow margin of chalcopyrite, pyrite, and pyrrhotite 5 feet long, while on the other side there is a small body of magnetite, 5 feet long, with maximum width of 30 inches, which contains a few grains of chalcopyrite. In the shaft, which represented the most southerly point on the property at which work had been attempted, an irregular body of pyrrhotite, containing some pyrite and chalcopyrite, is exposed with a maximum width of 4 feet.

Mineralization has not been continuous along this zone, but small, more or less lenticular ore bodies containing the four minerals named, in different degrees of abundance, are arranged in a linear manner, somewhat after the manner of peas in a pod. The presence of the limestone, a rock very susceptible to replacement, together with fissuring, has permitted the passage of mineral-bearing solutions which gave rise to these ore bodies.

SHOAL BAY AND VICINITY.

During the years 1899 and 1900, mining operations almost entirely ceased in the vicinity of Shoal bay, Phillips arm and Frederick arm. At the time of our visit no work was being done, nor did we meet anyone who had been connected with the former mining activity of this area. The vast majority of the claim stakes were down, the roofs of some of the [illegible] shafts and slopes were full of water. It was therefore impossible to make a satisfactory examination of the mines and prospects.

Gold values are associated with quartz veins and silicified bands which traverse narrow schistose "roof-curtains," and the marginal parts of the bodies of intrusive plutonic rocks. Within these narrow bands of highly altered stratified rocks, chiefly metamorphosed argillites, metamorphism has been so

intense that they have been largely converted to chlorite and hornblende schists, while the marginal portions of the plutonic rocks are locally very rich in hornblende and frequently display a gneissoid appearance. Along certain zones, and especially in the vicinity of the schistose rocks, quartz veins are numerous, usually trending in a northwest to southeast direction corresponding to the regional strike. Within any given zone these veins are found to die out, while others appear upon following the general direction of strike. The individual quartz veins are extremely irregular, both in width and continuity. The quartz veins, and occasionally the adjacent rocks, have been mineralized in a very irregular manner with iron sulphides, with which a little copper pyrites is frequently associated. In a few instances, a few specks of galena and zinc blende were noticed to be present with the quartz.

These quartz veins and their mineral contents originated during the period when the interior portions of the batholith of muscovite-biotite granite was cooling. After they were formed minor faulting has taken place, as is evidenced by the frequency of narrow shear zones, slickensided surfaces, and offsetting of the quartz veins and igneous dykes.

The *Doratha Morton* is situated at an elevation of about 2,600 feet, about 1¼ miles west of Fanny bay on Phillips arm. The ruins of a stamp mill and cyanide plant are situated on the shores of this bay, and formerly an aërial tramway connected this mill with the mine. In the vicinity of the contact between the granite and highly altered sedimentary rocks, there is a zone about 150 feet wide, in which quartz veins are of frequent occurrence. Not only the quartz veins, but some of the schistose rocks have been irregularly impregnated with auriferous pyrite. The major portions of the workings were in such a dilapidated condition that they could not be examined. Two tunnels were entered. One was driven about 630 feet at a distance of 540 feet from its mouth cross-cuts have been made. This tunnel shows the altered argillites, now very rich in hornblende, to be traversed by a large number of quartz veins, some of which contained considerable pyrite, and occasionally a few specks of chalcopyrite and sphalerite. The ore deposits were formed prior to the injection of the dark basic dykes, which are so common in the region. Another

tunnel, 94 feet in length, displays the same features, with more direct evidence of faulting. What seemed to be the tunnel leading to the main workings could only be entered for a distance of 30 feet. Between five to six hundred feet northward two large open cuts expose quartz veins traversing granite. The largest of these veins is 8 feet wide and contains some finely disseminated pyrite. From December 1898, to November 1899, the Doratha Morton yielded $90,000 in gold and silver bullion. It was then closed down because "the pay "ore was only in pockets and not in chutes," and "they ex-"hausted all the ore in sight."

The *Douglas Pine* is situated at an elevation of about 950 feet, on the slope of the mountain eastward from Shoal bay. Quartz veins bearing pyrite and a little chalcopyrite traverse a dark hornblendic gneiss. The uppermost tunnel, driven for 60 feet, starts on a quartz vein about 2 feet wide, which soon passed into numerous stringers. Another tunnel displays a vein of quartz 7 inches wide at the face. Another tunnel extends for 130 feet to a slope or shaft full of water. Beginning on a quartz vein, 9 feet wide, containing considerable pyrite, the tunnel shows that this body of quartz soon frays out into a large number of veins. Along this tunnel are two cross-cuts, 45 and 60 feet long, both of which terminate in quartz stringers traversing the country rock, and showing very little evidence of mineralization. Another shaft was full of water.

Upon the *Alexandra* mineral claim, which is situated on the western shore and near the entrance of Phillips arm, two tunnels have been driven. The upper tunnel is 279 feet long, in direction N. 45° W., terminating in a face 5 feet wide, of massive siliceous material, which in thin section under the microscope is seen to be composed of finely brecciated feldspar and quartz particles, cemented together by a matrix of quartz. This material is poorly mineralized with pyrite. Another tunnel near the shore extends N. 47° W. for about 715 feet, in a direction corresponding to the strike of the narrow band of schistose rocks. At intervals of 295, 565, and 715 feet cross-cuts have been driven to right and left. The schists are traversed by a multitude of veinlets of quartz. All of the veins of quartz, as well as the adjacent schists, contain a little pyrite, which is very irregularly distributed.

For further information concerning the mines and prospects of the Shoal Bay region, consult the reports of the Minister of Mines, British Columbia, 1898, pp. 1138-1143; 1899, pp. 798-800 and 806-807; 1900, p. 926.

[illegible]

On the northern shore of Heyden bay, and about [illegible] from its entrance, the "Heyden Bay" claim has been staked. The country rock is a dark diorite, which is traversed by dykes, the majority of which are aplites. A quartz vein carrying a small amount of pyrite and a few scattered grains of chalcopyrite, emanates from a pegmatite dyke in which crystals of muscovite, up to an inch across, are abundant. At its contact this dyke has altered the diorite to a chlorite schist, a thin zone of the schist separating the quartz vein from the pegmatite. The vein, which has been stripped for a distance of 30 feet, has a maximum width of 17 inches. It is traversed by two narrow dykes of diabase, showing that it antedates the invasion of the region by basic dykes. At the surface the quartz is more or less honeycombed, owing to the removal of the sulphides by weathering.

On Argillite point, about three miles farther with[illegible] inlet, quartzites, argillites, and a few thin bands of limestone are exposed along the shore. Their general strike is N. 45° W. while the dip varies from 10° to 90°. The argillites, and especially the quartzites, have been impregnated with irregularly disseminated [illegible] and [illegible], the presence of which imparts [illegible] appearance to the weathered surface and has led to the sta[illegible] of [illegible] claims.

On the opposite shore of this [illegible], and about two [illegible] south of T[illegible] head, the hills adjacent to the [illegible] are [illegible]ed by highly altered argillites, and limestones which have been penetrated by dark dykes. Along the shore [illegible] presence of these stratified rocks can only be detected by a small exposure of limestone, and by the general appearance of a dark diorite which occurs for a distance of about 700 feet. The diorite contains numerous inclusions and is similar in character to that at many other localities where plutonic rocks are in direct contact with the argillites.

PLATE XVII.

Prospecting tunnel at contact between limestone and augite syenite, Loughborough inlet.

At the immediate contact with the limestone, the plutonic rock is a light coloured augite-syenite which seems to be of more recent age than the diorite, and which is very variable in the size of its component mineral grains shading from a fine-grained aplite at contact to a fairly coarse-grained rock within a short distance. Here quite extensive prospecting operations have been carried on by the Cuba Silver Mining Company. Near sea-level tunnels have been driven with a total length of 280 feet. A tunnel follows the contact for 75 feet (see Plate XVII) and has exposed a body of pyrite which is apparently of an irregular lenticular shape with a length of about 20 feet and a maximum width of 3 feet. A winze has been sunk on the ore body, and shows that the ore almost entirely pinches out with depth.

The pyrite has a peculiar, uniform, silvery-white appearance, is massive, and it is reported that some assays made from samples collected near the surface ran $17 of gold per ton.

The greater portion of the tunnelling (165 feet) was in a direction N.55°E., with the hope of meeting a mineralized zone in the argillites, which outcrop at an altitude of a few hundred feet above sea level. For a width of 6 feet the argillites are very irregularly impregnated with pyrite, and a very little chalcopyrite. Previous to the attempt to strike this mineralized zone at the lower level a tunnel had been driven along it for a distance of 90 feet.

A few hundred yards northward, beyond a projecting point, a claim called the "Shamrock" has been located. Two short tunnels, one of which is visible from the shore, have been driven into the stratified series, where the latter contain scattered grains of pyrite. One thin layer of limestone which is exposed near the mouth of the tunnel, has been almost completely altered to garnet, tremolite, and pyroxene.

HURTADO POINT.

On the Full Moon mineral claim on *Hurtado point*, near Lund, at the contact between the plutonic rocks and a small roof-curtain of argillites and greenstones, the latter are sufficiently impregnated with pyrite and a little chalcopyrite to become very rusty on weathered surfaces. Numerous dark dykes of diabase traverse the other rocks. Two shafts have been sunk, one of which is 35 feet and the other 20 feet deep. The first shaft is situated at the immediate contact. The widely disseminated mineralization is of such a character that nothing approaching an ore body seems to exist here. Along the shore this small patch of stratified rocks weather in many shades of brown, red, and yellow, owing to the oxidation of the small particles of sulphides which they contain.

THEODOSIA ARM.

In the vicinity of the entrance to Malaspina inlet, and in Theodosia arm, the plutonic rocks, locally, have the appearance of barely having their roof removed. Small dark patches which are skirted by the granitic rocks on every side, though highly altered, have preserved within them traces of their original stratification. Between Martin point and Ellen point, such greenstones, argillites, and quartzites outcrop along the shore. The dip varies from 30° to 70°, while the strike also varies, but is generally toward the northwest. Locally these rocks contain disseminated particles of pyrite, and at one point a small pit, which is visible from the shore, has been made in what seems to have been a small pocket of ore containing magnetite, pyrite, and a little chalcopyrite.

At a distance of about three miles inland from the head of Theodosia arm there is reported to be a small area of crystalline limestone, upon which have been located certain mineral claims with showings of chalcopyrite.

IRON POINT, TWIN ISLANDS.

At *Iron point*, on the southern island of the Twin islands, which are situated immediately south of Cortez island in the Gulf of Georgia, a small patch of argillites and limestones locally weather in blacks and reds because of the presence of small amounts of magnetite and pyrite which occur as disseminated grains through these rocks.

### TOBA INLET.

Along the southern shore of Toba inlet the number of dark inclusions which the granite contains increases eastwardly until at a point which bears S. 49° E. from the point marking the entrance of Salmon bay, the plutonic rock is [illegible]ual contact with a patch of the altered stratified series. The latter consist of volcanic greenstones and porphyrites, argillites, and quartzites, all of which have been locally altered to a schistose condition. Small dykes of the granite freqently enclose large inclusions of these latter rocks. In some places granite borders the shore line, while the cliff above is composed of the metamorphosed stratified rocks. In places the contact is exposed only at low tide. About two hundred yards along the shore from the point located, two tunnels, 15 and 50 feet long respectively, penetrate zones along which the rock contains a few scattered grains of pyrite.

### FANNY BAY.

On the northern shore of Fanny bay, on North passage, at a point near its entrance, irregular patches upon the steep cliffs of granite are conspicuously stained with green carbonate of copper. The granite is traversed by narrow veins, the most of which contain only quartz. One small vein with a maximum width of 3 inches, carries a little molybdenite and chalcopyrite; another, with a maximum width of 6 inches, contains a small amount of galena. Near these veins was the corner post of the *Blue Bird* mineral claim, which had been staked in April, 1907, and upon which no traces of development work could be found.

### VILLAGE ISLAND.

On the northeastern corner of Village island, near the entrance of Knight inlet, some of the beds of the stratified series contain a few grains of bornite, chalcopyrite, pyrite, and galena.

### MARS ISLAND.

On the southeastern shore of Mars island, in the archipelago of Queen Charlotte sound, there is a small patch of stratified rocks consisting of thin-bedded quartzites and limestones. The latter are very generally altered to gar-

net, epidote, sphene, and vesuvianite, the garnets displaying remarkable optical anomalies. These rocks are in a vertical position, being the remnant of the lowest portion of a small roof-curtain. A few scattered grains of galena were noticed in one of the beds of altered limestone. Some of the quartzites are impregnated with pyrite, a little bornite and chalcopyrite. Two small particles of free gold were adhering to the face of a joint plane traversing one of the quartzite beds, but an assay of a portion of the adjacent rock, containing a little pyrite and bornite, did not reveal the presence of a trace of gold.

## Building and Ornamental Stones.

Within this region there are numerous excellent opportunities for establishing quarries in granite which is eminently suitable for building and ornamental purposes. Even though the demand at present is supplied from quarries which are nearer the markets, some of these localities seem worthy of investigation by those engaged in this business, because of the superior quality of the stone, and the ease with which it may be transported by water.

In Walsh cove, on the eastern shore of West Redonda island, there is an exposure of beautiful pink granite, which is so traversed by joint planes that quarrying should be relatively easy. The harbour facilities are good, the water remaining deep quite near the shore. It is a coarse-grained biotite granite, containing two feldspars. This granite is somewhat similar to the celebrated Baveno granite from the vicinity of Lago de Maggiore, in Italy, but the shade of pink is more delicate and its general appearance even more pleasing. The orthoclase, which is more abundant than the plagioclase, is of a rich pink colour; the plagioclase, ranging from albite to oligoclase in composition, is greyish-white. In thin section under the microscope the orthoclase is very turbid because of kaolinization, while the plagioclase, which is much fresher, is partially altered to sericite and epidote. The biotite is quite generally altered to a chlorite which polarizes in a deep blue colour, the chloritization having been associated by the separation of a little secondary magnetite. Quartz is abundant and there has been a slight tendency for this mineral to enter into micrographic intergrowth with the ortho-

clase. Crystals of sphene, a few of which are of such size that they are visible to the naked eye, are relatively abundant, usually approximating closely to their habitual wedge-shaped outlines. A few grains of epidote, some of which are so distinctly pleochroic that it seems probable that they approach allanite in composition, are also present. Two small crystals of zircon, a few short, needle-like prisms of apatite, and a small grain of pyrite were noticed within a single thin section.

A granite which to all external appearances is similar to that from Walsh cove, but which does not occur under such favourable circumstances for quarrying, occurs near the head of Pendrell sound on East Redonda island and also in the vicinity of Dean point on the northeastern corner of West Redonda island.

At a distance of about 27 miles within Bute Inlet, the massive Granite Mountain rises, almost devoid of vegetation from the water's edge to an altitude of 6,653 feet. It is composed chiefly of a medium-grained biotite granite of a greyish-white colour, which would be a very serviceable and satisfactory building stone. In hand specimen, the rock displays a faint gneissoid structure. Upon examination under the [illegible], the rock is remarkably fresh. Orthoclase and an [illegible] plagioclase are present in about equal amount. Several [illegible] individual crystals of the former are twinned according to the Carlsbad law, some of the plagioclase in addition to excellent polysynthetic twinning display good zonal structures. A small amount of microcline is also present. The biotite is very fresh, its pleochroism ranging from very dark brown to a light straw-yellow. The quartz frequently possesses a [illegible] undulatory extinction. Magnetite occurs in [illegible] formed crystals, or in aggregates of small irregular grains. A little epidote, a few small needles of apatite and numerous small crystals of zircon complete the mineralogical composition of this rock.

A pink granite on the southern shore of Squirrel cove, on the east side of Cortez island, a somewhat similar granite [illegible] Bones bay on the northern shore of Cracroft, and grey hornblende granites on the west shore of Port Harvey, and at a point on the southern shore of Kwatsi bay or Thompson

sound, are of such good quality that they would make attractive building stones and so situated that they may be quarried with moderate ease.

The orbicular hornblende-gabbro, from a small island to the west of Midsummer island and to the north of Fire island in Queen Charlotte sound, would furnish a unique and very beautiful building stone.

## Clays, Lime and Cement.

Some of the post-glacial, marine clays which were observed near the shores of some of the bays on Reade island, in the bed of a stream which enters Open bay on S. Valdes island, on the south side of Maurelle island about a mile and a half from Surge narrows, in the bed of a stream just west of Roy P. O., in Loughborough inlet, and in a cove on the south shore of Port Elizabeth on Gilford island, are probably suitable for the manufacture of bricks, tiles, etc. In general, these clays are characterized by a bluish colour, a compact texture and a tenacious habit when wet. Some of them are so nearly impalpable that they might well be used for an abrasive or polishing powder. Mr. E. W. Wylie of Burdwood bay, Reade island, informed the writer that he used such clay, taken from a deposit immediately back of his house, for lining his cooking stove and that it proved to be satisfactory in every way. The following analysis of a typical sample of the clay from this deposit was made by Mr. A. O. Hayes while a senior student in chemistry at McGill University:—

| | | | |
|---|---|---|---|
| $SiO_2$ | 60.86 | $K_2O$ | 2.73 |
| $Al_2O_3$ | 16.64 | $Na_2O$ | 3.55 |
| $Fe_2O_3$ | 7.34 | $H_2O$ (hygroscopic) | 0.34 |
| $CaO$ | 5.72 | $H_2O$ (combined) | 2.01 |
| $MgO$ | 3.30 | | |
| | | | 99.49 |

Many of the limestones of the Marble Bay formation are particularly pure and upon burning should furnish excellent lime.

If at any time limestone be required as a flux in smelting ores, this rock may be readily obtained from the localities mentioned. It seems highly probable that a judicious mixture of powdered limestone with the post-glacial clays, described in the preceding paragraph, might be used for the manufacture of cement.

## ADDENDUM

### The Open Bay Group

This name is applied to a series of argillites or thinly bedded quartzites which rest conformably upon the more or less metamorphosed limestones of the Marble Bay formation, and pass beneath the volcanic rocks of the Valdes group. Some of the argillites are compact, fine-grained, and siliceous to such a degree that they may appropriately be called cherts. Individual strata of this group are seldom more than a few inches in thickness, and since these occupy steeply inclined or vertical positions, weathered surfaces present a striking ribboned appearance because of differential weathering. Locally they have been intruded by dark dykes and sheets of augite andesite and diabase, some of which were injected when the lava flows of the Valdes group were being poured forth, and others during the period of dyke injection that followed the invasion of the Coast Range batholiths.

They are typically developed in Open bay on the eastern side of South Valdes island, where, with a thickness of several hundred feet, they strike about N. 40° W. with very steep dips toward the south. Especially in the interior of South Valdes island they are traversed by minor faults, and by many dark dykes and thin sheets of the igneous rock-types referred to in the last paragraph. In some localities, as in Blinkensop bay, Port Neville, southern shore of West Thurlow island, and at Eden point, West Thurlow island, rocks which undoubtedly belong to this group were observed to be present directly beneath the volcanic rocks of the Valdes group. In part, at these localities what were apparently the more calcareous beds and some of the intercalated sheets of augite andesite have been metamorphosed to hornblende schists.

In general, upon the map they have not been distinguished from the "undifferentiated" rocks because, (1) if the limestones on the southern shore of Cardew channel and on the northern shores of Frederick and Phillips arms be regarded as Marble Bay formation of less thickness, then below these lime-

stones are a group of rocks which petrographically are quite similar to the Open Bay group, (2) the Parson Bay group, containing Triassic fossils and apparently resting conformably upon the Valdes group, when metamorphosed are quite lithologically similar to the habitual expression of the Open Bay group.

# INDEX

## A



## B



## C

## G



## H



## I

## L



## M



## O



## P

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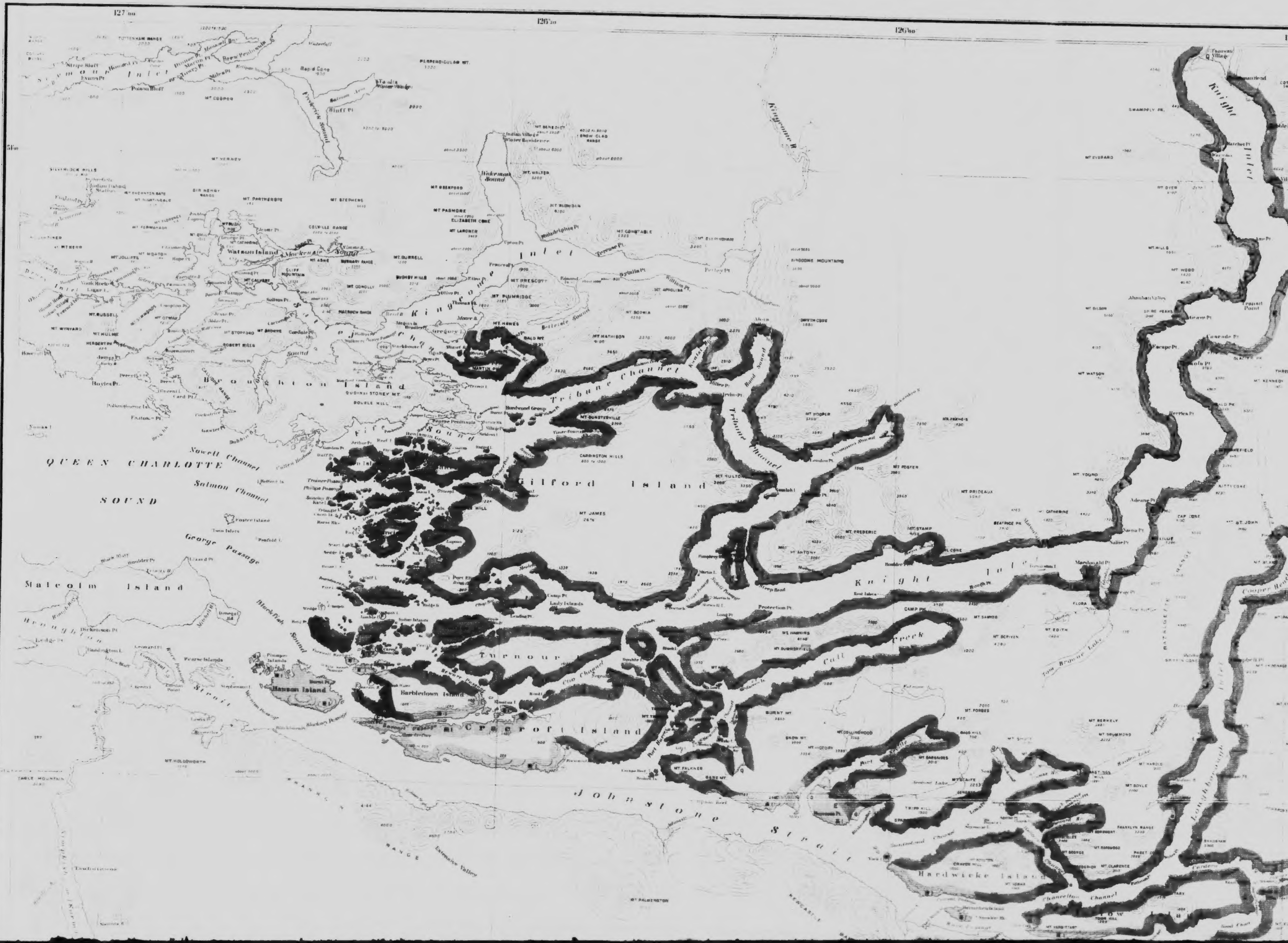
AREAL GEOLOGY




## LEGEND

| | | |
|---|---|---|
| QUATERNARY | GLACIAL AND RECENT | 0 Sand, gravel, clay |
| MESOZOIC | UPPER ? JURASSIC | Coast Range Intrusive |
| | TRIASSIC | Parson Bay group |
| | TRIASSIC (?) | Valdes formation |
| PALAEOZOIC | UPPER PALAEOZOIC | Open Bay group |
| | | F1 Marble Bay formation |

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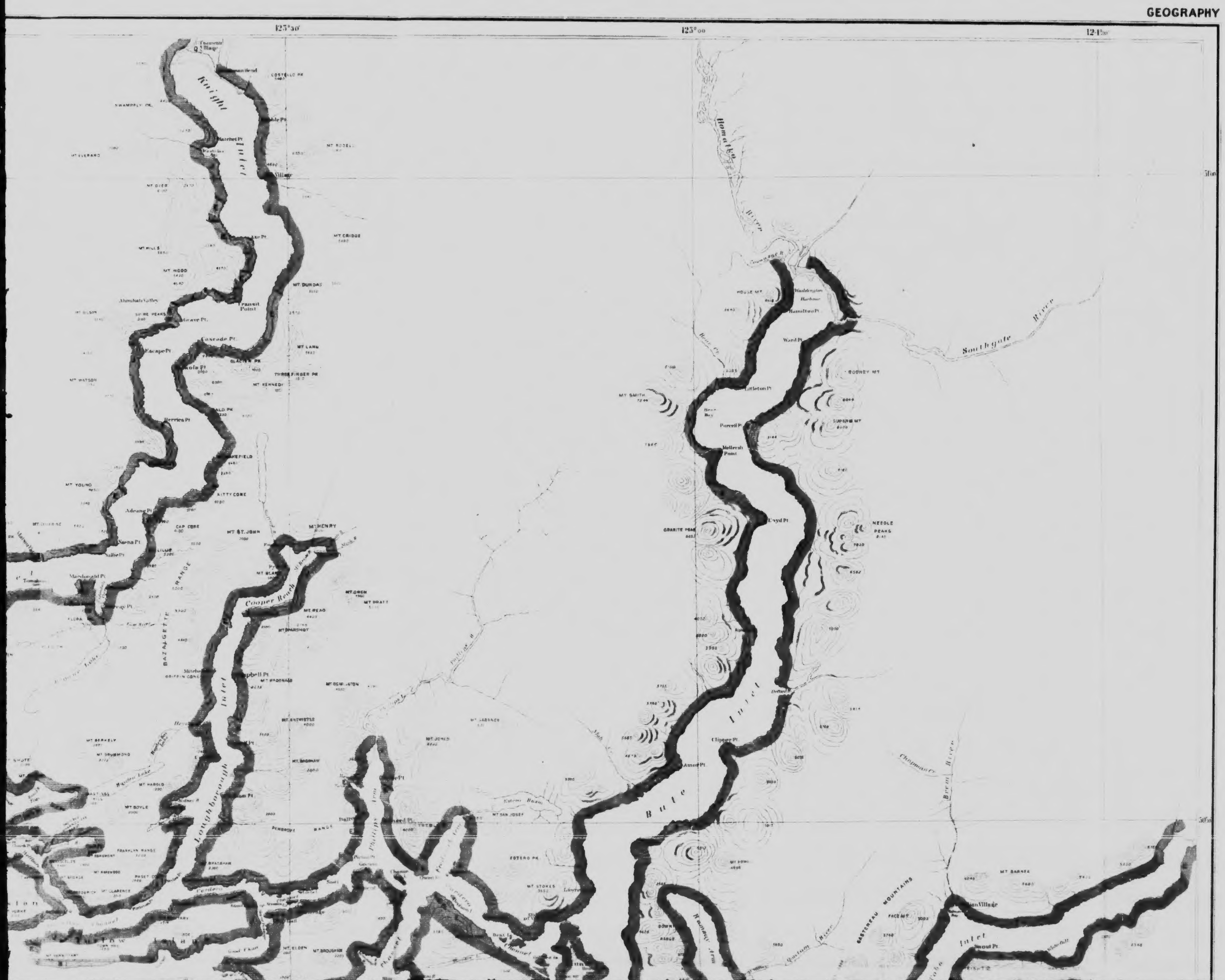


PALAEOZOIC

UPPER PALAEOZOIC

F2

Open Bay group

F1

Marble Bay formation

E

Undifferentiated

Symbols

Fossil locality

Geological boundary


...General, Geographer and Chief Draughtsman.
...uthorne, Draughtsman


Scale 35 miles to 1 inch

MAP 65A
(Issued 1913)

# COAST AND ISLANDS
## BETWEEN STRAIT OF GEORGIA AND QUEEN CHARLOTTE SOUND
### BRITISH COLUMBIA

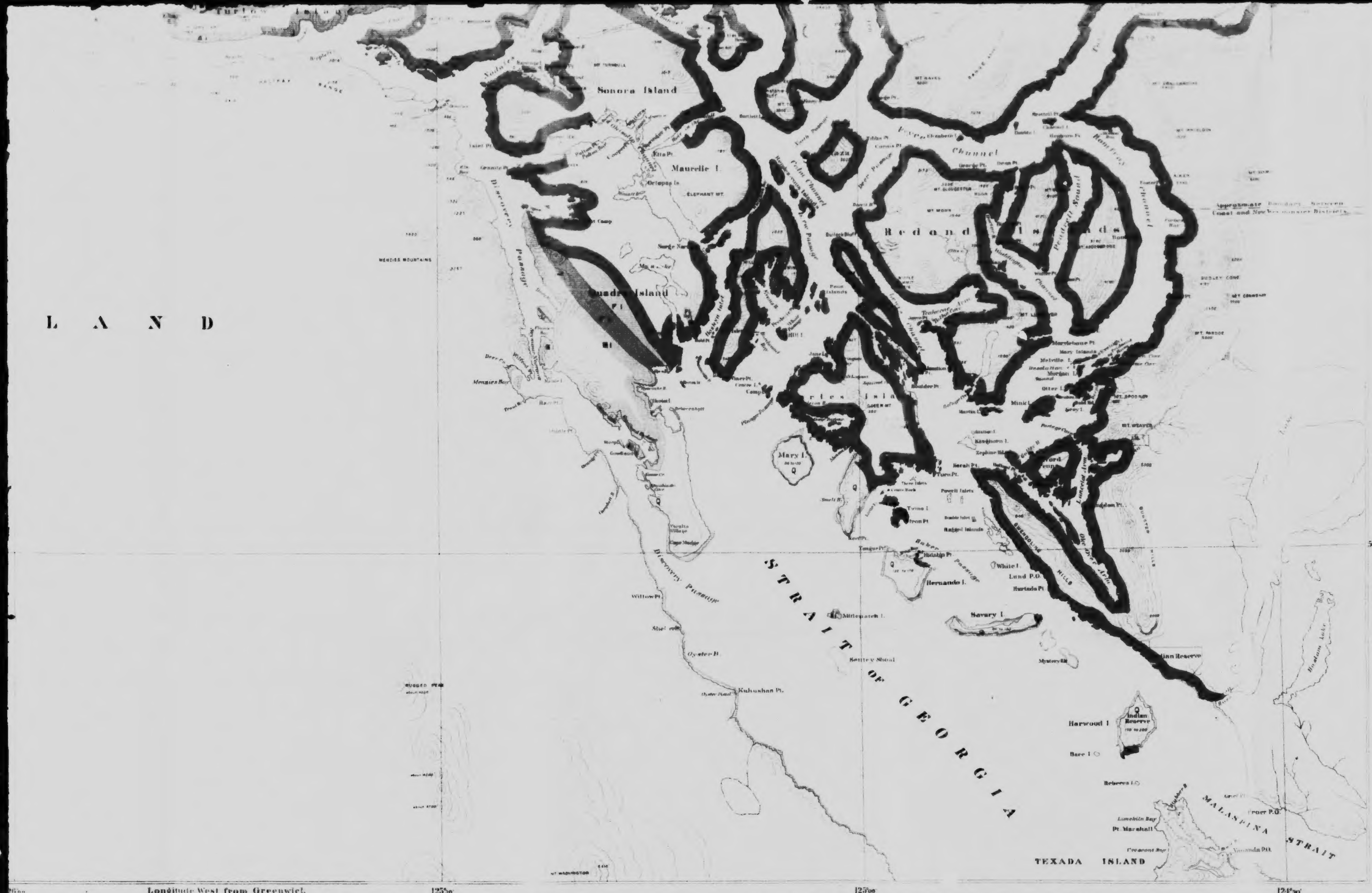
Scale, $\frac{1}{253,440}$

Miles

Kilometres

4 MILES TO 1 INCH

To accompany Memoir No. 23




MAP 65A
(Issued 1913)

# COAST AND ISLANDS
## EN STRAIT OF GEORGIA AND QUEEN CHARLOTTE SOUND
BRITISH COLUMBIA

Scale, $\frac{1}{253,440}$

Miles

Kilometres

4 MILES TO 1 INCH

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J. A. BANCROFT 1907

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